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IDENTIFIERS	*Conceptual Change; Environmental Action; Gender Issues

ABSTRACT

This proceedings of the 1997 Annual International Conference of the Association for the Education of Teachers in Science (AETS) includes a copy of the conference program and 43 papers and presentation summaries from the meeting, placed in order by conference session. Among the topics of the papers include are: reading-to-learn and writing-to-learn science activities, views and actions taken on global atmospheric change issues, disciplinary knowledge of science teachers, student teachers and curriculum reform, elementary education majors in an alternative content biology course, translating reform efforts to classroom practices, values and dissection, preservice science teachers self-efficacy, professional development for secondary science teachers, infusion of Native American culture, policy issues in Florida science teachers, constructivist learning environments, teacher preparation, nature of science, children's literature, video case studies in pre-service science teacher education, teacher research experience, the National Space Grant College and Fellowship, informal learning assay, collaboration in the classroom, cultural barriers for Hispanics and American Indians, women in science, elementary teachers' conceptions of science pedagogy, the Urban Systemic Initiative, gender differences in student attitudes, textbook analyses, science education partnerships in undergraduate science instruction, conceptual change, teacher education, visual learning logs, constructivist teaching practices, fifth-grade students perceptions about scientists, science education for students with disabilities, domestic violence, professional development, teaching teachers to teach through Technology and Invention in Elementary Schools (TIES), mentoring, alternative assessment, performance assessment, reform projects, and nature of scientific knowledge. (JRH)

ED 405 220

Proceedings of the 1997 Annual International Conference of the Association for the Education of Teachers in Science

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Edited by:
Peter A. Rubba, Penn State University
Patricia F. Keig, California State University -- Fullerton
James A. Rye, West Virginia University

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Preface

In the Fall 1994, when Pete Rubba proposed to the AETS Board of Directors that the association publish conference proceedings, the proceedings were conceived as a record of AETS annual meetings. Papers presented at and summaries of presentations made at AETS annual meetings would be included. The proceedings initially would be disseminated via the ERIC Clearinghouse for Science, Mathematics and Environmental Education in microfiche and hard copy form, and eventually also on the AETS World Wide Web Site. Given ERIC documents and web materials are not copyrighted, AETS presenters would be able to submit papers and presentation summaries published in the proceedings to journals such as the *Journal of Science Teacher Education* and *Science Education.*

Forty-three papers and presentation summaries from the 1997 AETS Annual Meeting in Cincinnati, OH were submitted for inclusion in the 1997 AETS Conference Proceedings. In reviewing them, we mainly made suggestions on ways to enhance clarity and formatting. Because the proceedings are to serve as the record of an AETS annual meeting, the papers and presentation summaries were not refereed.

The *Proceedings of the 1997 Annual International Conference of the Association for the Education of Teachers in Science,* includes a copy of the conference program and 43 papers and presentation summaries from the meeting, ordered by conference session. We are pleased to have had the opportunity to edit the 1997 AETS Conference Proceedings.

Peter A. Rubba, Penn State University
Patricia F. Keig, California State University -- Fullerton
James A. Rye, West Virginia University

Acknowledgment

The editors gratefully acknowledge the assistance of Dana Stuchul, Vicki Brungart, and Cathy Hipple in helping to compile these proceedings.

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1997 AETS Conference Program

ASSOCIATION FOR THE EDUCATION OF TEACHERS IN SCIENCE, 1997 ANNUAL INTERNATIONAL CONFERENCE, JANUARY 9-12, 1997: CINCINNATI, OHIO.

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1997 AETS ANNUAL INTERNATIONAL MEETING
JANUARY 9-12, 1997
OMNI NETHERLAND PLAZA - CINCINNATI, OHIO

Welcome to the 1997 Annual AETS Meeting in Cincinnati, Ohio. The **Omni Netherland Plaza**, a National Historic Landmark and Cincinnati's most critically acclaimed hotel, is located in the heart of downtown Cincinnati near a variety of diverse attractions. The hotel, across from Fountain Square, is part of the Carew Tower complex and adjacent to Tower Place - a myriad of fine stores, shops, entertainment, and eateries. The city's famous sky walk system connects the hotel to the convention center, downtown commercial district, and other downtown shopping, dining, and recreation. The hotel is within walking distance to Riverfront Stadium, Coliseum, Music Hall, Taft Theater, and the Arnoff Center. The **Omni Netherland Plaza** is itself a tourist attraction, boasting such priceless treasures as the renowned Hall of Mirrors, one acre of rare Brazilian Rosewood paneling, and spectacular ceiling murals. We hope you enjoy your accommodations, the meeting facility, and Cincinnati's nearby attractions during your conference stay!

The sponsors for this conference are Delta Education, Miami University, and Colorado College. As a member of AETS and a conference attendee, please let these sponsors know how much you appreciate their support of AETS.

Sincerely, The Conference Planning Committee

A Special Conference Welcome by AETS President, Paul J. Kuerbis

Welcome to Cincinnati and to the fifth annual AETS International conference! We owe the entire conference planning team our sincere thanks and appreciation for the work they have done in putting together a superb program. The ultimate success of the conference, however, is determined by each of you, individually and collectively. Many of you contributed to the design of the conference through thoughtful and pertinent paper and special session proposals. All of you will contribute through your constructive comments and real dialogue (not just discussion) during each of the sessions and in the hallways and byways of the convention locale. In the short time we have been having annual conferences we have become known as a group of thoughtful colleagues who have gathered to share ideas and research and to learn as much as we can from each other. I want to encourage your complete participation in the conference by also inviting you to drop in on committee and board meetings and to let the leadership know how you can contribute to the fulfillment of the AETS mission: to promote leadership in, and support those involved in, the professional development of teachers of science.

Sincerely, Paul J. Kuerbis, 1996 President

Registration Location and Hours

The registration area is located in the Pavilion Foyer on the fourth floor in the Omni Hotel. Hours of registration are: Thursday from 10:00-5:30 PM, Friday from 7:30-5:00 PM, and Saturday from 8:00-12:00. In addition to matters pertaining directly to conference registration, updates regarding changes for this years conference will be located in this area, as well as materials and information about the 1998 conference being held in Minneapolis and other printed materials about timely science teacher education matters.

Amenities

Coffee and other beverages will be available during a coffee break in the Pavillion Room between 9:30 and 10:00 AM on both Friday and Saturday.

SPECIAL EVENTS

There are several special events that have been included within your conference registration. These include two evening receptions, the Invited Speaker Luncheon, and the Annual Awards Ceremony/Business Meeting Luncheon. The specific dates, times, locations, and descriptions of these events are as follows:

OPENING RECEPTION

Thursday, January 9, 5:30-6:30 PM, Omni Hotel, Continental Room, Mezzanine Level

The Opening Reception, sponsored by Miami University and Colorado College, is intended to be an initial informal social gathering on the evening of the first day of conference activities. The reception will be held in the Omni Netherland Plaza and will be an opportunity for attendees to relax while enjoying light hors d' oeuvres. A single soft drink ticket is included with registration. A cash bar will be available.

INVITED SPEAKER LUNCHEON

Friday, January 10, 12:30-2:30 PM, Omni Hotel, Pavillion

The guest speaker at this luncheon will be Dr. Ramon Lopez, University of Maryland, Astrophysics Department. The title and a summary of Dr. Lopez's presentation are as follows:

"Elementary Science Education Reform and Roles for Scientists"

Reform in elementary science education is receiving increasing attention nationwide, and scientists in particular are asking what role they may play. The American Physiological Society (APS) has begun an effort to mobilize the scientific community in support of meaningful reform, and the ways in which the APS and scientists are working with school districts around the country to support that reform.

CINCINNATI ZOO AND BOTANICAL GARDENS EVENT

Friday, January 10, 6:30-9:30 PM, sponsored by Delta Education

Enjoy the wonders of the Cincinnati Zoo with your colleagues! Take a tour of C.R.E.W., the Center for Reproduction of Endangered Wildlife, see a demonstration of the zoo's WEB site, and pet wild animals! Hor d' oeuvres and drinks will be served. Buses will depart from the 5th St. Hotel entrance at 6:30 PM and arrive back at the hotel at 9:30 PM.

ANNUAL AWARDS CEREMONY/BUSINESS MEETING LUNCHEON

Saturday, January 11, 12:30-2:30 PM, Omni Hotel, Pavillion

This luncheon will serve as the venue for the presentation of the AETS Annual Awards and the Annual Business Meeting. A list of these awards and previous recipients are found on pages 34 through 36 of this program.

1997 AETS Annual Meeting
January 9-12, 1997
Omni Netherland Plaza Hotel
Cincinnati, Ohio

Thursday, January 9, 1997

8:00 A.M. - 12:00 P.M. AETS Board Meeting with lunch - Salon I
1:00 P.M. - 5:00 P.M. - Preconference Workshop
3:00P.M. - 6:00 P.M. -- Registration - Pavillion Foyer
5:30 P.M. - 6:30 P.M. - Reception at Omni Netherland Plaza Hotel sponsored by Miami University (MUH, EAP, EDT), Colorado College - Continental Room

Friday, January 10, 1997

6:30 A.M. - 7:50 A.M. -AETS Committee Meetings
8:00 A.M. - 8:30 A.M. -Continental Breakfast
8:30 A.M. - 9:30 A.M. -Sessions 101 - 108
Coffee Break - Pavillion
10:00 A.M.-11:00 A.M.-Sessions 201-208
11:15 A.M.-12:15 P.M.-Sessions 301-308
12:30 P.M. -2:30 P.M. - Luncheon With Speaker - Pavillon
2:45 P.M. -3:45 P.M. - Sessions 401-408
4:00 P.M. -5:00 P.M. - Sessions 501-508
7:00 P.M. -9:00 P.M. - Reception at the Cincinnati Botanical and Zoological Gardens (Buses leave hotel at 6:30P.M.)

Saturday, January 11, 1997

8:00 A.M. - 9:30 A.M. Registration - Pavillion Foyer
8:00 A.M. - 8:30 A.M. - Continental Breakfast
8:30 A.M. - 9:30 A.M. - Sessions 601-608
Coffee Break - Pavillion
10:00 A.M.-11:00 A.M.Sessions 701-708
11:15 A.M.-12:15 P.M.-Sessions 801-808
12:30 P.M. -2:30 P.M. - Lunch - AETS Business Meeting - Pavillon
2:00 P.M. - 3:00 P.M. - Registration - Pavillion Foyer
2:45 P.M. -3:45 P.M. - Sessions 901-908
4:00 P.M. -5:00 P.M. - Sessions 1001-1008
5:15 P.M. -6:30 P.M. Special Session

Sunday, January 12, 1997

6:30 A. M. - 7:50 A.M. - Committee/Task Force Meetings
8:00 - Noon - AETS Board Meeting with breakfast - Salon I
8:30 - Noon - Workshops
9:00 AM - 10:00AM - Sessions 1101-1103

PRE-CONFERENCE WORKSHOP

Classroom-Based, Embedded Assessment in Science ***Salon B***

Classroom-based, embedded assessment is a significant way for science teachers to improve their teaching and student learning in science classes. Through research and development sponsored by NSF and Michigan State University, a process and support materials have been developed to assist middle school science teachers in adding this form of assessment to their repertoire of skills. The experience of developers suggests that the approach can also be effectively used by elementary and high school teachers. During this workshop science teacher educators will be introduced to the materials and approach. Join us and discuss plans to consider build a community of science teacher educators to pursue this work further and explore teacher change through these assessment techniques. Limited to 40 participants.

Presenters: James Gallagher, Joyce Parker, and Cooperating Teachers ***Thursday 1:00-5:00***

Friday, January 10, 1996

6:30 - 7:50 A.M.

Committee Meetings and Room Assignments:

Elections Committee - Salon B
Program Committee - Salon F
Publications Committee - Salon D
Awards Committee - Salon G
International Science Education - Caprice 2
Financial Advisory Committee - Caprice 3
Ad Hoc Committee on Science Teacher Educator Standards - Caprice 1
Ad Hoc Committee on Professional Development for Science Teacher Educators - Caprice 1
Ad Hoc Committee on Electronic Communications - Rosewood
Ad Hoc Committee on Corporate Sponsorship for AETS Activities - Rosewood
Ad Hoc Committee on Mentoring New Members - Salon B
Ad Hoc Committee on Structure and Finances of the AETS Annual Meetings - Salon D
Committee for Inclusive Science Education - Salon H

Saturday, January 11, 1996

6:30 - 7:50 A.M.

Committee Meetings and Room Assignments:

Membership Committee- Salon B
Long Range Planning Committee - Salon F
Committee for Inclusive Science Education - Salon D
Committee on Liaisons with Professional Organizations of Science Educators - Salon G
Science Teacher Education Section Editorial Board for Science Education - Caprice 2
Journal of Science Teacher Education Editorial Board - Caprice 3
Ad Hoc Committee on Dissemination and Implementation of the National Science Education Standards, Benchmarks, and (AAAS) Blueprint on Science Teacher Education - Caprice 1
Ad Hoc Committee on Liaison with Scientific Societies - Caprice 1
Ad Hoc Committee on Science Faculty Development - Rosewood
Ad Hoc Committee on Liaison with INTASC - Rosewood
Ad Hoc Committee on Regional AETS Units - Salon B
NCATE Subcommittee of NSTA Science Teacher Education Committee - Salon D
Committee for Inclusive Science Education - Salon H

CONCURRENT SESSIONS
FRIDAY 8:30 A.M. - 9:30 A.M.

101 Reading and Writing to Learn Science Activities for the Elementary Classroom
Hand-on Workshop -60 minutes Elementary Caprice 1
Presenters: **James A. Shymansky**, University of Iowa,Iowa city, IA
Larry D. Yore, University of Victoria, Victoria, BC, Canada
JoAnne Lewis, University of Iowa,Iowa city, IA
Jennifer Chidsey, University of Iowa,Iowa city, IA
Laura Henriques, University of Iowa,Iowa city, IA
Presider: **Marcia K. Fetters**, University of North Carolina, Charlotte, Charlotte, NC
Participants will learn how to use an array of reading and writing to learn strategies for use with hands-on activities in the elementary school grades

102A Children's Science Content Knowledge: If Teachers Knew, What Would They Do Differently?
Demonstration - 30 minutes Elementary/College Salon F
Presenter: **Patricia F. Keig**, California State University, Fullerton, CA
Presider: **Jeanie Roberson**, Vanderbilt University, Nashville, TN
Demonstration methods lesson illustrates experiences to guide teachers in the use of new assessment practices. Teachers' responses to this new knowledge and instructional changes that followed.

102B Views About and Actions Taken on Global Atmospheric Change Issues by Middle and HS Teachers of Science Participating in an STS Teacher Enhancement Institute
Contributed Paper - 30 minutes Middle/College/Supervision Salon F
Presenters: **Peter A. Rubba**, Pennsylvania State University, University Park, PA
James A. Rye, West Virginia University, Morgantown, WV
Leigh A. Boardman, Pennsylvania State University, University Park, PA
Presider: **Jeanie Roberson**, Vanderbilt University, Nashville, TN
This paper examines the effects of a teacher enhancement institute on global atmospheric change issues and STS instruction on participants' views and actions on GAC.

103 Building a Successful Collaborative for Professional Development: Lessons Learned and Recommendations
Panel - 60 minutes General Salon B
Presenters: **James P. Barufaldi**, University of Texas at Austin, Austin, TX
Kamil A. Jbeily, University of Texas at Austin, TX
Katherine I. Norman, Cal. State - San Marcos, San Marcos, CA
Lisa S. Leach, Region 17 Education Service Center, Lubbock, TX
Presider: **James Barufaldi**, University of Texas at Austin, TX
Strategies for creating successful collaborative partnerships for the professional development of science teachers will be discussed in a report on the development of Texas Collaboratives.

104A The Integration Challenge: Reforming the Secondary Math and Science Methods Classrooms
Contributed Paper - 15 minutes College/Univ Caprice 2
Presenters: **Fletcher Brown**, University of Montana, Missoula, MT
David Erickson, University of Montana, Missoula, MT
Presider: **Peter Vernesi**, SUNY College at Brockport, Brockport, NY
This presentation discusses the barriers and rewards methods, high school, and preservice teachers experienced while reforming math and science classrooms to model integrated teaching practices.

104B Teachers' Perspectives on Development Projects:How Do They Make Sense?
Contributed Paper -15 minutes College Caprice 2
Presenter: **Kathryn Powell**, Texas A&M, Bryan, TX
Presider: **Peter Vernesi**, SUNY College at Brockport, Brockport, NY
Experienced teachers in development projects bring unique processes for sense-making. Those processes can act as a filter for what content and pedagogy the teachers will take with them from the project.

104C Middle Level Science Teachers' Ability to Think Critically: Are They Dormant in the Context of Teaching?

Contributed Paper - 15 Minutes Middle Caprice 2
Presenter: **Frank L. Holmes**, Oregon State University, Corvallis, OR
Presider: **Peter Vernesi**, SUNY College at Brockport, Brockport, NY

The realm of the middle level science classroom, vibrant with many active minds pondering the concrete aspects of science, may be missing the abstract (i.e., critical thinking) portion. This may be because the classroom teachers' thinking skills are also not awakened.

105 Connecting the Curriculum Through the National Science and Mathematics Standards

Hands-on Workshop - 60 minutes College/University Salon G
Presenter: **Raymond Francis**, Appalachia Educational Laboratory, Charleston, WV
Presider: **Mike Nelson**, University of Wisconsin-Whitewater, Whitewater, WI

The National Science and Mathematics Standards provide the foundation upon which an integrated curriculum can be built. In this workshop, participants will work with an effective approach to connecting the curriculum.

106A Teachers Beliefs and Their Implementation of Constructivism In Their Classroom

Contributed paper - 30 minutes General Salon D
Presenter: **Judy Beck**, University of Wisconsin-LaCrosse, LaCrosse, Wisconsin
Presider: **Ed Jones**, Miami University, Oxford, OH

The purpose of this study was to examine the influences of teacher beliefs on their intent to implement constructivism in their classroom

106B Preservice Science Teacher Education, The National Science Education Standards, and Equity: Collaboration is the Key

Contributed paper - 30 minutes General Salon D
Presenters: **Bambi Bailey**, University of Delaware, Newark, DE
Susan Gleason,Middletown High School, Middletown, DE
Kathryn Scantlebury, University of Delaware, Newark, DE
Ellen Johnson, University of Delaware, Newark, DE
Presider: **Ed Jones**, Miami University, Oxford, OH

Results of collaborative research between university science educators and cooperating teachers attempting to encourage preservice science teachers to interact equitably with their students.

107A An Exploratory Study of the Disciplinary Knowledge of Science Teachers

Contributed paper - 30 minutes College/Univ/Supervisory Rosewood
Presenter: **Fouad Abd-el-khalick**, Oregon State University, Corvallis, OR
Presider: **Deborah Tippins**, University of Georgia, Athens, GA

Science teachers' disciplinary knowledge is described in terms of their knowledge of the structure, function and development of their disciplines and their understanding of the nature of science.

107B Student Teachers Within Curriculum Reform: Does a Label Make a Difference?

Contributed Paper - 30 minutes College Rosewood
Presenter: **Joan M. Whitworth**, Morehead State University, Morehead, KY
Presider: **Deborah Tippins**, University of Georgia, Athens, GA

This paper presents three case studies of student teachers engaged in practice teaching at curriculum reform sites. Characteristics of each reform and their effects on the students teachers is examined.

108 Using Hypermedia To Enhance Teacher Development

Demonstration - 60 minutes College/University Caprice 3
Presenters: **Andrew Lumpe, Southern** Illinois University, Carbondale, IL
Jodi J. Haney, Bowling Green State University, Bowling Green, OH
Presider: **Christine Ebert**, University of South Carolina, Columbia, SC

We will demonstrate hypermedia strategies including electronic portfolios, WWW, HTML programming, and published programs designed for science teachers. Handouts and disks provided.

FRIDAY 10:00 A.M. - 11:00 A.M.

201 Modeling the Learning Cycle with Preservice Middle and Secondary Science Teachers

Hands-on-workshops - 60 minutes Middle/HS Caprice 2
Presenter: **John R. Staver**, Kansas State University, Manhattan, KS
Presider: **David Westwood**, Ohio State University, Columbus, OH

I will model a lesson with participants in which the concept of chemical equilibrium is presented via the Learning Cycle.

202A Attitudes and Experiences of Preservice Elementary Ed majors as They Experience an Alternative Content Bio Course

Contributed Paper - 30 minutes General Salon B
Presenters: **David T. Crowther**, University of Nevada/Reno, Reno, NV
Ron Bonnstetter, University of Nebraska-Lincoln, Lincoln, NE
Presider: **M.O. Thirunarayanan**, Rowan College, Galssboro, NJ

This presentation will discuss a substantive theory generated from a multiple cross case qualitative study on the experiences of elementary preservice teachers in an experimental content biology course.

202B Portfolio Dilemmas: Are We Really Learning About Our Students?

Contributed Paper - 30 Minutes College/Supervision Salon B
Presenters: **Meta Van Sickle**, University and College of Charleston, Charleston, SC
William Baird, Auburn University, Auburn, AL
Presider: **M.O. Thirunarayanan**, Rowan College, Galssboro, NJ

Five universities studied portfolio development that were used to replace exit exams. Questions that were dilemmas for students and professors were studied. Preliminary recommendations are made.

203 CASE Project to Develop New NSTA/NCATE Standards for Science Teacher Preparation

Panel - 60 minutes General Salon G
Presenters: **Steven W. Gilbert**, Indiana University Kokomo, Kokomo, IN
Norman Lederman, Oregon State University, Corvallis, OR
Hans O. Andersen, Indiana University, Bloomington, IN
Robert L. Fisher, Illinois State University, Normal, IL
Barbara Spector, University of South Florida, Tampa, FL
Paul Kuerbis, The Colorado College, Colorado Springs, CO
Presider: **Valarie L. Dickinson**, Oregon State University, Corvallis, OR

Panel will discuss new basic and advanced standards for science teacher education that are data-driven and competency-based. An expert network to disseminate the standards will be discussed.

204A Translating Current Science Reform Efforts Into Classroom Practices

Contributed Paper - 15 minutes Elementary/Middle/College Salon D
Presenter: **Farella Shaka**, Southwest Missouri State University, Springfield, MO
Presider: **M. Virginia Epps**, University of Wisconsin- Whitewater, Whitewater, WI

This paper describes and discusses the results of a teacher enhancement program designed to enable teachers to adopt new science teaching strategies and curriculum reform.

204B The Instructors' Reflections on a New Constructivist Science Curriculum for Prospective Elementary Teachers

Contributed paper - 15 minutes Elementary Salon D
Presenter: **Ling Liang**, Indiana University, Bloomington, IN
Presider: **M. Virginia Epps**, University of Wisconsin- Whitewater, Whitewater, WI

PIPS curriculum has potential in improving both prospective teachers' and instructors' understanding of science knowledge and their underlying views about teaching and learning science.

204C The Effect of Hands-On, Kit-Based Instructions on Fourth Grade Teachers' Knowledge

Contributed paper - 15 minutes Elementary Salon D
Presenters: **Molly Weinburgh**, Georgia State University, Atlanta, GA
Michael Hughes, Emory University, Atlanta, GA
Presider: **M. Virginia Epps**, University of Wisconsin- Whitewater, Whitewater, WI

This session describes the effect of a two day hands-on inservice on 4th grade teachers' content knowledge and confidence in teaching kit-based science.

205 Free Access to Educational Resources on the Internet

Demonstration - 60 minutes Elementary/Middle/High School Caprice 3
Presenter: **Kim Roempler**, Eisenhower National Clearinghouse for Mathematics & Science Ed.
Presider : **David Jackson**, University of Georgia, Athens, GA

Tour ENC's online educational resources and the ways these resources can be used to enhance and expand mathematics and science curriculum.

206 Visual/Spatial Thinking and the Creation of a Constructivist Curriculum

Panel - 60 minutes Elementary/Middle School Caprice 1
Presenters: **Allan McCormack**, San Diego State University, San Diego, CA
Cheryl L. Mason. San Diego State University, San Diego, CA
Presider: **Catherine Yeos**, Wichita State University, Wichita, KS

Visual/spatial thinking skills are key human intellectual/sensory image processing abilities that may be used as key organizers for a truly constructivistic science curriculum.

207A Cooperative Learning that Really Works in Science Teaching: Constructivism

Contributed Paper - 30 minutes High School/College Rosewood
Presenter: **Thomas R. Lord**, Indiana University of Pennsylvania, Indiana, PA
Presider: **Vicki D. Harry**, Clarion University of Pennsylvania, Clarion, PA

Presenter will focus on constructivist-based activities used in cooperative group settings with college level science students. He will also discuss activities that do not work with cooperative learning in science classes.

207B Engagement, Wonder and Learning by Jerks In Science: Perspectives of Preservice Elementary Education Students, Medical Students, and Research Science Doctoral Students

Contributed Paper - 30 minutes General Rosewood
Presenters: **Nancy Pelaez**, Indiana University School of Medicine, Indianapolis, IN
Kim Ryder, Indiana University School of Medicine, Indianapolis, IN
Michael R. Cohen, Indiana University School of Medicine, Indianapolis, IN
Presider: **Vicki D. Harry**, Clarion University of Pennsylvania, Clarion, PA

Views of science learning by students at different educational levels and the implications for science instruction and integration between levels.

208A The Final Frontier: An Investigation of the Incorporation of Sequenced Writing Genre to Increase Student Science Comprehension of Earth and Space Science Concepts

Contributed Paper - 30 minutes High School/College Salon F
Presenter: **Kathie Black**, University of Victoria, Victoria, BC, CA
Presider: **Larry D. Yore**, University of Victoria, Victoria, BC, CA

The premise of this work is to explore writing as an integral part of the learning process itself and not just as the periphery of communication of final ideas in assessment form.

208B Values, Dissection, and School Science: An Inquiry Into Students' Construction of Meaning

Contributed Paper - 30 minutes High School/College Salon F
Presenters: **Elizabeth Doster**, University of Georgia, Athens, GA
Allen L. Emory, University of Georgia, Athens, GA
Presider: **Denise K. Crockett**, University of Georgia, Athens, GA

This session questions how the values found in the secondary science curriculum relate to the personal values of individual students and how these students assign meaning.

FRIDAY 11:15 A.M. - 12:15 P.M.

301 The Role of Teachers and Science Educators: Adapting and Accessing New Technologies to Survive Hostile Environments

Hands-On-Workshop - 60 minutes General Caprice 3
Presenters: **J. Russett**, Purdue University Calumet, Hamond, IN
Betsy Price, University of Utah, Salt Lake City, UT
Presider: **Paul Vellom**, Ohio State University, Columbus, OH

For the computer phobic and those who will be accessing the internet through a modem, a computer with limited memory, or a system that is slow to download.

302A Community Service Activities for Pre-Service Teachers
Contributed Paper - 15 minutes College Caprice 2
Presenter: **Michael Grote**, Ohio Wesleyan University, Delaware, OH
Presider : **Jodi J. Haney**, Bowling Green State University, Bowling Green, OH

Several projects allowing pre-service science teachers to apply classroom content to solving needs in the local community will be discussed.

302B Influence of an Extended elementary Science Teaching Practicum Experience Upon Preservice Elementary Teachers' Science Self-efficacy
Contributed paper - 15 minutes General Caprice 2
Presenter: **John R. Cannon**, Univ. of Nevada, Reno, NV
Presider: **Jodi J. Haney**, Bowling Green State University, Bowling Green, OH

This research investigated the influence, or lack thereof, of an extended elementary science teaching practicum upon preservice elementary teachers' science self-efficacy.

302C Understanding the Learning Cycle: Influences on Abilities to Embrace the Approach By Preservice Elementary School Teachers
Contributed paper - 15 minutes General Caprice 2
Presenter: **John Settlage**, Cleveland State University, Cleveland, OH
Presider: **Jodi J. Haney**, Bowling Green State University, Bowling Green, OH

Considerations among self-efficacy and learning cycle test measures were used to evaluate how these factors explained students' abilities to comprehend this instructional approach.

303 Curriculum Materials for Science Literacy
Hands on Workshop - 60 Minutes General Caprice 1
Presenter: **Jo Ellen Roseman**, AAAS/Project 2061, Washington, DC
Presider: **Jo Ellen Roseman**, AAAS/Project 2061, Washington, DC

In this hands-on workshop, participants will find out more about Project 2061's curriculum analysis procedure and will have an opportunity to try out a shortened version of the procedure themselves.

304 Teach Till It Hurts! or What Does It Take to Affect Change?
Demonstration - 60 minutes General Salon F
Presenters: **Craig Berg**, UW-Milwaukee, Milwaukee, WI
Michael Clough, Memorial High School, Eau Claire, WI
Presider: **Randy L. Bell**, Oregon State University, Corvallis, OR

It takes a rigorous sequence of activities to facilitate change in preservice teacher's ideas about learning and the role of the teacher from didactic teacher-centered instruction to student-centered instruction that is more in line with development and conceptual change teaching.

305A Evaluation of the National Teachers Enhancement Network: Enhancing Teachers' Science Content Knowledge Using Telecommunications
Contributed Paper - 30 minutes High School/College Salon B
Presenter: **P. Sean Smith**, Berea College/Horizon Research Inc., Berea, KY
Presider: **Aaron Burke**, Project Discovery, Kettering, OH

This paper will focus on the design of and major findings from the evaluation of a unique approach to enhancing science teachers' content knowledge.

305B The Health Sciences and Technology Academy: Professional Development for Secondary Science Teachers Through a Community-based Curriculum Enrichment Program for Underrepresented Students
Contributed Paper - 30 minutes High School/College Salon B
Presenter: **James Rye**, West Virginia University, Morgantown, WV
Presider: **Aaron Burke**, Project Discovery, Kettering, OH

Secondary science teachers in West Virginia gain professional development through facilitating science clubs that provide extended investigations and orientation to health professions for under represented students.

306A Review of NSF Comprehensive Curricula for Middle School Science
Contributed Paper - 30 minutes Middle School Rosewood
Presenters: **James Ellis**, The National Science Foundation, Arlington, VA
Janice Earle, The National Science Foundation, Arlington, VA
Presider: **Barbara A. Crawford**, Oregon State University, Corvallis, OR

NSF program directors will report on a review of NSF comprehensive curricula for middle school science and will provide copies of the review instrument.

306B An Eisenhower Science and Mathematics Constructivist/Cultural Integration Project In a Dakota Tribal School
Contributed Paper - 30 minutes General Rosewood
Presenters: **Paul B. Otto**, University of South Dakota, Vermillion, SD
Sherry Johnson, Tiospa Zina Tribal School, Agency Village, SD
Presider: **Barbara A. Crawford**, Oregon State University, Corvallis, OR

A one year project which emphasized hands-on teaching science and mathematics based upon the Dakota Culture. The Robert Karplus Learning Cycle was the mechanism for a constructivist approach to teaching science and mathematics.

307 Elementary Science Teacher Education: Who Are We?
Panel - 60 minutes Elementary Salon G
Presenters: **Julie Thomas**, Texas Tech University, Lubbock, TX
M. Jenice French, Kansas State University, Manhattan, KS
Jon E. Pedersen, East Carolina University, Greenville, NC
Presider: **William Boone**, Indiana University, Bloomington, IN

This interactive panel/audience discussion will explore the way in which personal history and teaching philosophy guide the definition of an elementary science methods course.

308A Developing a Multicultural Sci. Ed. Curriculum: A Primer For Science Educators
Contributed Paper - 30 minutes General Salon D
Presenter: **S. Maxwell Hines**, University of Louisville, Louisville, KY
Presider: **Penny L. Hammrich**, Temple University, Philadelphia, PA

This session is designed to aid novice science teacher educators in multicultural science teacher education curriculum development.

308B Action Research of Elementary School Teachers
Contributed Paper - 30 minutes Elementary/College/General Salon D
Presenters: **Penny J. Gilmer**, Florida State University, Tallahassee, Fl
Jane Barco McDonald, Florida State University, Tallahassee, Fl
Presider: **Penny L. Hammrich**, Temple University, Philadelphia, PA

Describes the Action research component of a science teacher enhancement program: a research methods course, choosing of topic, mentoring, conduction of elementary research. Examples given.

LUNCH with Speaker 12:30 P.M. - 2:30 P.M.

FRIDAY 2:45 P.M. - 3:45 P.M.

401 Activities for Science Educators on Teaching Science to Students with Disabilities
Hands-on-workshops - 60 minutes General Caprice 1
Presenter: **Greg P. Stefanich**, University of Northern Iowa, Cedar Falls, IA
Presider: **Dorthy L. Gabel**, Indiana University, Bloomington, IN

Participants will engage in activities drawn fro a training model being developed for the preparation of preservice teachers on teaching science to students with disabilities.

402A Changing Science Teaching Paradigms Among College Science Faculty: An Emerging Practical Model for Institutional Change At Small Colleges
Contributed Paper - 30 minutes General Caprice 2
Presenter: **B. Patricia Patterson,** Wesley College, Dover, DE
Presider: **Bill Baird**, Auburn University, Auburn, AL
A case study describing constructivist shifts in a college science teacher. Data suggests a practical model for teaching change among college faculty and the educator's role.

402B Policy Issues in Florida Teacher Education-Role and Impact of the Higher Education Consortium for Mathematics and Science (HEC)
Contributed Paper - 30 minutes College/Univ Caprice 2
Presenter: **Marianne B. Barnes**, University of North Florida, Jacksonville, FL
Lehman W. Barnes, University of North Florida, Jacksonville, FL
Presider: **Bill Baird**, Auburn University, Auburn, AL
A discussion of the evolution of the HEC will occur, with emphasis on Florida's emerging K-16 plans for teaching education in six geographical regions.

403A A Three Year Study of Teachers' Beliefs Regarding the Implementation of Integrated Science Units
Contributed Paper - 30 minutes Elementary/Middle/College Salon D
Presenter: **Charlene Czerniak**, University of Toledo, Toledo, OH
Presider: **Janet Bohren**, University of Cincinnati, Cincinnati, OH
This session will explore teachers' beliefs regarding the implementation of integrated science units on the Great Lakes region after they participated in a year-long Eisenhower Program.

403B Gender Issues in Systemic Reform of Science Education
Contributed Paper - 30 minutes Elementary/Middle/High/College Salon D
Presenter: **Maria M. Ferreira**, Indiana University, Bloomington, IN
Presider: **Janet Bohren**, University of Cincinnati, Cincinnati, OH
A study of graduate students in science indicates that many females experience the same differential treatment that causes many girls to stay away from a career in science. Implications and recommendations for teacher education are discussed.

404A Comparing Teaching Practice with Student Outcome Knowledge: An Assessment of Constructivist Learning Environments K-7
Contributed Paper - 30 minutes General Salon F
Presenters: **Larry Flick**, Oregon State University, Corvallis, OR
Valarie Dickinson, Oregon State University, Corvallis, OR
Norman G. Lederman, Oregon State University, Corvallis, OR
Presider: **Erica Brown**, Columbus, OH
The purpose of the study was to assess student knowledge that resulted from the implementation of constructivist teaching practices learned during ISC workshops.

404B A Review of Science Teaching Self-efficacy Beliefs Research
Contributed Paper - 30 minutes General Salon F
Presenters: **Larry Enochs**, UW-Milwaukee, Milwaukee, WI
Tracy Posnanski, UW-Milwaukee, Milwaukee, WI
Iris Riggs, California State University-San Bernardino, San Bernardino, CA
Margaret Gail Shroyer, Kansas State University, Manhatten, KS
Presider: **Erica Brown**, Columbus, OH
This presentation will provide a review of the research on science teaching self-efficacy beliefs and a synthesis of the findings. A complete bibliography will be provided.

405A The Maryland Collaborative for Teacher Preparation: Making Sense of the Enactment of Reform in the Preparation of Specialist Teachers of Mathematics and Science

Contributed Paper - 30 minutes   Middle/College/University   Rosewood
Presenters: **J. Randy McGinnis**, University of Maryland, College Park, MD
Tad Watanabe, Towson State College, Towson, MD
Gilli Shama, University of Maryland, College Park, MD
Amy Roth-McDuffy, University of Maryland, College Park, MD
Steve Kramer, University of Maryland, College Park, MD
Presider: **George R. Davis**, Moorhead State University, Moorhead, MN

This session will share insights emerging from a longitudinal, multi-level, multi-dimensional resource program devoted to documenting a interpreting this NSF funded systemic teacher preparation program.

405B Portfolios as Authentic Assessment of Prospective Elementary Science Teachers' Professional Development

Contributed Paper - 30 minutes   Elementary   Rosewood
Presenter: **Sheila M. Jasalavich,** Marist College, Poughkeepsie, NY
Presider: **George R. Davis**, Moorhead State University, Moorhead, MN

Learn how portfolios are used to assess the professional development of prospective elementary science teachers during different phases of the Marist College teacher education program.

406 Enhancing Science Methods Courses Through the Integration of Projects Learning Tree, Wild, and Wet

Hands-On-Workshop - 60 minutes   General   Salon B
Presenters: **Catherine Yeotis**, Wichita State University, Wichita, KS
Twyla Sherman, Wichita State University, Wichita, KS
Presider: **Mark D. Guy**, The university of North Dakota, Grand Forks, ND

Presenters will model how these programs are integrated into both elementary and secondary science methods courses, and will explain how preservice teachers use them during their methods field experiences.

407 Transforming A Department Amidst Calls for Reform in Science Teacher Education: Lessons From History

Panel-60 minutes   College/Univ   Salon G
Presenters: **Frank E. Crawley**, East Carolina University, Greenville, NC
Floyd Mattheis, East Carolina University, Greenville, NC
Charles R. Coble, East Carolina University, Greenville, NC
Presider: **Clifford A. Hofwolt**, Vanderbilt University, Nashville, TN

Three persons present an overview of the problems and dilemmas faced by faculty and administrators during three critical periods of one department's history.

408 Training Teachers to Use the Internet to Enhance Science Instruction, The WV K-12 RuralNet Project

Panel-60 minutes   General   Caprice 3
Presenters: **Randall L. Wiesenmayer**, West Virginia University, Morgantown, WV
George Meadows, West Virginia University, Morgantown, WV
Peter A. Rubba, Penn State University, University Park, PA
Sally Kelly, Terra Alta Middle School, Terra Alta, WV
Kirk Lantz, Terra Alta Middle School, Terra Alta, WV
Presider: **Michael Jay**, MediaSeek Technologies, Bellingham, WA

An overview of the West Virginia K-12 RuralNet Project's summer teacher training workshops, on-line courses, and evaluation results.

FRIDAY 4:00 P.M. - 5:00 P.M.

501 Teaching the Nature of Science in a Geology Course Designed for Pre-service Teachers

Hands-on-workshops - 60 minutes   General   Caprice 2
Presenter: **William Slattery**, Wright State University, Dayton, OH
Presider: **Linda Ramey-Gassert**, Wright State University, Dayton, OH

This workshop will feature hands-on activity designed to bring the methods of scientific inquiry into the classroom. Many activities will be based in internet/www sites.

502A Teaching for Excellence K-8 Science Education: Using Project 2061 Benchmarks For More Effective Science Instruction

Contributed paper - 15 minutes College/Univ Caprice 3

Presenter: **Penny L. Hammrich**, Temple University, Philadelphia, PA

Presider: **Patricia F. Keig**, California State University Fullerton, Fullerton, CA

In this presentation, I will describe a model for utilizing national science reform initiatives in an elementary science course.

502B Science Education Reform

Contributed Paper - 30 minutes General Caprice 3

Presenters: **Valerie K. Olness**, Augustana College, Sioux Falls, SD
John Clementson, Augustana College, Sioux Falls, SD

Presider: **Patricia F. Keig**, California State University Fullerton, Fullerton, CA

K-8 inservice teachers are introduced to constructivism, its relationship to the Benchmarks and the National Science Standards, and the implication for their teaching.

503 Creating Multidisciplinary Authentic Experiences In Elementary Methods Course

Panel - 60 minutes Elementary Caprice 1

Presenters: **Julia McArthur**, Bowling Green State University, Bowling Green, OH
Margot Fadool, Bowling Green State University, Bowling Green, OH
Dean Cristol, Bowling Green State University, Bowling Green, OH
Jan Schnupp-Lee, Bowling Green State University, Bowling Green, OH

Presider: **Kirk A. Reinkens**, Washington State University, Richland, WA

Teacher educators from several content areas (science, social studies, language arts, and reading) will discuss collaborative strategies used in elementary courses.

504 Analyzing and Using Children's Literature to Connect school Science with Parents and Home

Hands on Workshop - 60 Minutes Elementary Salon G

Presenters: **Jennifer L. Chidsey**, University of Iowa, Iowa City, IA
Laura Henriques, California State University, Long Beach, CA

Presider: **Kevin D. Finson**, Western Illinois University, Macomb, IL

This interactive workshop demonstrates the potential of using book bags to introduce, assess and contextualized science instruction with an eye towards motivational opportunities and instructional platforms.

505 From the Medium to the Message: 3 techniques for Preservice Teacher Education

Panel - 60 minutes Middle/High/College/Supervisory Salon F

Presenters: **Paul Vellom**, Ohio State University, Columbus, OH
Marcia K. Fetters, University of North Carolina - Charlotte, Charlotte, NC
David Westwood, Ohio State University, Columbus, OH

Presider: **Kenneth J. Schoon**, Indiana University Northwest, Gary, IN

Three techniques (case studies, goal directed learning and problem-based learning) as use in methods classes and supervision are examined. Examples and materials are provided.

506A Collaborative Research on the Education of Science Teachers in the US and Japan

Contributed Paper - 30 minutes Elementary/Middle/High Rosewood

Presenters: **Joseph P. Riley II**, University of Georgia, Athens, GA
Michael J. Padilla, University of Georgia, Athens, GA

Presider: **Lawrence F. Wakeford**, Brown University, Providence, RI

This paper describes a cross cultural collaborative research effort between the University of Hiroshima and the University of Georgia to compare the preparation of science teachers on teacher development and students achievement.

506B Distance Education, Hands-on Science and Reform

Demonstration - 30 minutes College/Univ Rosewood

Presenter: **William Boone**, Indiana University, Bloomington, IN

Presider: **Lawrence F. Wakeford**, Brown University, Providence, RI

Interactive distance education technology can help provide hands-on science as part of a systematic reform effort. this session will provide live footage of many broadcasts.

507 The Impact of the Teacher Research Experience: Learning "Real" Science in a "Real" Context

Panel - 60 minutes Middle/High/College Salon B
Presenters: **Patricia Obenauf**, West Virginia University, Morgantown, WV
Eric J. Pyle, West Virginia University, Morgantown, WV
Sue Ann Heatherly, NRAO- Greenbank, Greenbank, WV
Debra Hemler, West Virginia University, Morgantown, WV
Aimee Barden, West Virginia University, Morgantown, WV
Bruce Gansneder, West Virginia University, Morgantown, WV
Joe Evans, Glenville State College, Glenville, WV
Warren DiBiase, West Virginia University, Morgantown, WV
Presider: **P. Sean Smith**, Berea College/Horizon Research Inc.,Berea, KY

This panel discussion will include the development and impact of a series of research experiences for inservice and preservice science teachers from several perspectives.

508A The National Space Grant College and Fellowship Program: Implementing National Standards

Contributed Paper - 30 minutes General Salon D
Presenter: **Michael R.L. Odell**, NASA Headquarters, Washington, DC
Presider: **Gary Varrella**, University of Iowa, Iowa City, IA

This session will present NASA's Space Grant Program and it plan for implementing national science, mathematics, and technology standards. Opportunities for training and funding will be presented.

508B Development of an Informal Learning Assay

Contributed Paper - 30 minutes College/Univ Salon D
Presenters: **Brian L. Gerber**, Valdosta State University, Valdosta, GA
Edmund A. Marek, University of Oklahoma, Norman, OK
Ann M.L. Cavallo, University of Oklahoma, Norman, OK
Presider: **Gary Varrella**, University of Iowa, Iowa City, IA

This presentation describes the development and field testing of an instrument that examines the wide variety of informal learning experiences a child may encounter.

SATURDAY 8:30 A.M. - 9:30 A.M.

601 Teaching Grant Proposal Writing Basics to Science Teachers

Hands-on-workshops - 60 minutes College/Unvi Caprice 2
Presenters: **Diana Hunn**, University of Dayton, Dayton, OH
Lloyd Barrow, University of Missouri, Columbia, MO
Presider: **Jan Woerner**, California State University, San Bernardino, CA

We will complete several activities used in a science methods course for graduate students who are interested in learning basic skills of grant proposal writing.

602 Science Methods' Professors: Should We Be Guarding the Gates to the Science Teaching Profession? If So, How?

Panel - 60 minutes College/Univ Caprice 1
Presenters: **Ann E. Haley-Oliphant**, Miami University, Oxford, OH
Barbara S. Spector, University of South Florida, Tampa, FL
Presider: **Robert Boram**, Morehead State University, Morehead, KY

The necessity for, and feasibility of how methods professors can identify unsuitable teaching candidates prior to student teaching is a reliable, valid manner will be discussed.

603A Collaboration in the Classroom: A Framework for Research and Practice

Contributed paper - 15 minutes General Salon F
Presenter: **Barbara A. Crawford**, Oregon State University, Corvallis, OR
Presider: **Napoleon A. Bryant Jr.**, Cincinnati, OH

A framework for creating and analyzing a community of learners in a science classroom will be explored.

603B Can Effective Professional Development Occur in a Three Week Summer Institute

Contributed paper - 15 minutes General Salon F
Presenter: **Aaron Burke**, Project Discovery, Kettering, OH
Presider: **Napoleon A. Bryant Jr.**, Cincinnati, OH

Recent reforms in professional development for science teachers are advocating 4-6 week summer institutes. The effectiveness of three week total immersion institutes will be explored in this presentation.

603C Teachers As Scientists

Contributed paper - 15 minutes General Salon F
Presenter: **Teresa Hislop**, University of Utah, Salt Lake City, UT
Presider: **Napoleon A. Bryant Jr.**, Cincinnati, OH

The "Teachers as Scientists" course takes Utah science teachers to the ocean where they act as scientists so they can facilitate similar experiences for students.

604A Six Strategies to Help Science Students Read Graphics

Demonstration - 30 minutes College/Univ Rosewood
Presenter: **Virginia Anderson**, Townson State University, Towson, MD
Presider: **Michael R. Cohen**, Indiana University-Purdue University at Indianapolis, IN

Six strategies to help science students read graphics will be presented.

604B Interactive Multimedia for Teacher Education

Demonstration - 30 minutes General Rosewood
Presenters: **Thomas E. Thompson**, Northern Illinois University, DeKalb, IL
Beth A. Wiegmann, Northern Illinois University, DeKalb, IL
Alan Voelker, Northern Illinois University, DeKalb, IL
Stephen R. Wallace, Northern Illinois University, DeKalb, IL
Ken King, Northern Illinois University, DeKalb, IL
Presider: **Michael R. Cohen**, Indiana University-Purdue University at Indianapolis, IN

This session will present a demonstration of videodiscs and software for preservice and inservice teachers by exemplary elementary science teachers. Supporting documentation will also be shown.

605A Powerful Ideas in Physical Science: A Constructivist Course for Prospective Elementary Teachers

Demonstration - 30 minutes College/Univ Caprice 3
Presenter: **Dorothy L. Gabel**, Indiana University, Bloomington, IN
Presider: **Ronald L. Fiel**, Morehead State University, Morehead, KY

The content, philosophy, and implementation of this new four unit physical science course will be presented and illustrated using the "Nature of Matter" unit.

605B Developing and Acting Upon Ones' Conception of Science: The Reality of Teacher Preparation

Contributed Paper - 30 minutes General Caprice 3
Presenters: **Randy L. Bell**, Oregon State University, Corvallis, OR
Norman G. Lederman, Oregon State University, Corvallis, OR
Fouad Abd-El-Khalick, Oregon State University, Corvallis, OR
Presider: **Ronald L. Fiel**, Morehead State University, Morehead, KY

this research presents a detailed analysis of preservice teachers understanding of the nature of science and factors mediating its translation into classroom practice.

606 Science and Special Education Teachers as Partners in Retooling Science Assessments

Hands-on Workshop (60 minutes) Elementary/Middle Salon B
Presenter: **Kevin D. Finson**, Western Illinois University, Macomb, IL
Presider: **Walter S. Smith**, University of Akron, Akron, OH

We will retool a science assessment following project guidelines so that it is appropriate for special education and general education students.

607 Inclusive Science Education: What does It Look Like?

Panel - 60 minutes College/Univ Salon G

Presenter: **Janice Koch**, Hofstra University, Hempstead, NY
S. Maxwell Hines, University of Louisville, Louisville, KY
Dale Merkle, Shippensburg University, Bay City, MI
Virginia Epps, University of Wisconsin - Whitewater, Whitewater, WI
Paula Neville, University of Wisconsin - Whitewater, Whitewater, WI

Presider: **Janice Koch**, Hofstra University, Hempstead, NY

Five science teacher educators address issues of gender equity, multiculturalism, sexual orientation and students with disabilities as they explore access and equity in science education.

608 New Science Teachers' Views of Their Preparation Programs: A Cross-site Analysis

Panel- 60 minutes Middle/High/College Salon D

Presenter: **Robert James**, Texas A&M University, College Station, TX
Kristin T. Hamm, Texas A&M University, College Station, TX
Kathryn Labuda, Texas A&M University, College Station, TX
Mark Twiest, Indiana University of Pennsylvania, Indiana, PA
Kazi Hossain, Indiana University of Pennsylvania, Indiana, PA
Herbert K. Brunkhorst, California State University, San Bernardino, CA
John Tillotson, Syracuse University, Syracuse, NY

Presider: **Bonnie Brunkhorst**, California State University, San Bernardino, CA

This session presents the SALISH Project data on new teacher perceptions from four institutions with different teacher preparation programs.

SATURDAY 10:00 A.M. - 11:00 A.M.

701 Barriers for Hispanics and American Indians Entering Science and Mathematics: Cultural Delemmas

Panel - 60 minutes General Caprice 3

Presenter: **Rey Ramirez, Jr**., U. of Texas at Brownsville, Brownsville, TX
Katherine I. Norman, Cal State - San Marcos, San Marcos, CA
Elva G. Laurel, University of Texas at Brownsville, Brownsville, TX
Joseph Keating, Cal State - San Marcos, San Marcos, CA

Presider: **Sherry Nichols**, University of Texas at Austin, Austin, TX

The nature of cultural influences will be reported as comparative results and antidotes of interviews with Hispanic students, parents, educators and scientists in California and Texas.

702A Enhancing Objective Test Items; A Constructivist Use and View

Contributed paper - 15 minutes College/Univ Rosewood

Presenter: **Lucille Slinger**, University of Wisconsin-LaCrosse, LaCrosse, WI

Presider: **William Slattery**, Wright State University, Dayton, OH

The procedures and results of using a modified approach to objective items on exams in an elementary/middle level science methods course will be shared.

702B Changes in Preservice Elementary Teachers' Conceptions of the Nature of Science: A Qualitative/Quantitative Analysis

Contributed paper - 15 minutes College/Univ Rosewood

Presenter: **Richard L. Statler**, University of Utah, Salt Lake City, UT

Presider: **William Slattery**, Wright State University, Dayton, OH

The impacts of an elementary science methods course on preservice teachers' conceptions of the nature of science are explored through quantitative and qualitative measures. Significant results related to specific components of the course were identified.

702C Teacher Preparation in These Postmodern Times

Contributed paper - 15 minutes General Rosewood
Presenter: **John W. Tillotson**, Syracuse University, Syracuse, NY
Peter D. Veronesi, SUNY College at Brockport, Brockport, NY
Becky Meyer Monhardt, Utah State University, Logan, UT
Presider: **William Slattery**, Wright State University, Dayton, OH

The postmodernism movement has called into question current practices in science and science teaching. Hear scientists' views of post modernism and learn about the implications it has for science teacher education.

703A Woman, Wife, Mommy, and Scientist: Helping Females See Themselves in Science

Contributed Paper - 30 minutes General Salon B
Presenter: **Juanita Jo Matkins**, University of Virginia, Charlottesville, VA
Presider: **J. Preston Prather**, University of Virginia, Charlottesville, VA

A study of women scientists showed that women can have romance, marriage, and children and still be successful as scientists. Cases are presented for use in science methods courses.

703B An Equity Blueprint for Project 2061 Science Education

Contributed Paper - 30 minutes General Salon B
Presenter: **Sharon Lynch**, George Washington University, Washington, DC
Presider: **J. Preston Prather**, University of Virginia, Charlottesville, VA

The Equity Blueprint is one of twelve Blueprints Commissioned by AAAS Project 2061. It discusses the equity implications (both positive and negative) of science education reform for diverse groups.

704A Incorporating Vee Diagrams in Elementary/Middle Level Science Methods Courses

Contributed Paper - 30 minutes General Salon G
Presenters: **M. Virginia Epps**, University of Wisconsin-Whitewater, Whitewater, WI
Michael A. Nelson, University of Wisconsin-Whitewater, Whitewater, WI
Presider: **Larry Fick**, Oregon State University, Corvallis, OR

Vee diagrams are used in methods courses to prepare elementary/middle level preservice teachers to structure original investigations and to connect them to previous knowledge.

704B Volitional Change in Elementary Teachers' Conception of Science Pedagogy

Contributed Paper - 30 minutes Elementary/Supervision Salon G
Presenter: **Vickie D. Harry**, Clarion University of Pennsylvania, Clarion, PA
Presider: **Larry Fick**, Oregon State University, Corvallis, OR

This study documented and analyzed changes in the thoughts meanings, and beliefs of practicing elementary school teachers about science pedagogy via a Generative Learning Model of Teaching

705A Effects of Heterogeneous Cooperative Grouping In A Combined Secondary and Elementary Physical Science Methods Class

Cancelled

Contributed Paper - 30 minutes Elementary/Middle/High/College Caprice 1
Presenter: **Walter Bisard**, Central Michigan University, Mt. Pleasant, MI
Presider: **Marianne B. Barnes**, University of North Florida, Jacksonville, FL

A summary of the effects of heterogeneous cooperative grouping in a combined physical science methods class of prospective elementary, middle, and high school teachers.

705B Prototypic Authentic Assessments in Science and Mathematics

Contributed Paper - 30 minutes Elementary/Middle/High/College Caprice 1
Presenters: **Elizabeth Hammerman**, Northern Illinois University, Dekalb, IL
Diann Musial, Northern Illinois University, Dekalb, IL
Presider: **Marianne B. Barnes**, University of North Florida, Jacksonville, FL

This session allows participants to examine and critique several authentic assessments in science and mathematics that were developed using a constructivist process and are based on national standards.

Cancelled

706A Development and Validation of an Inquiry Teaching Performance Observational Instrument
Contributed Paper - 30 minutes Elementary/College/General Salon F
Presenters: **Joseph Jesunathadas**, California State University, San Bernardino, CA
Janet Woerner, California State University, San Bernardino, CA
Presider: **Iris Riggs**, California State University, San Bernardino, CA
A classroom observational instrument to evaluate the teaching performance of elementary teachers conducting guided inquiry lessons will be demonstrated. Development and validation procedures described.

706B Supporting Communities of Learners in Urban School Districts: Evaluating the Impact of the Urban Systemic Initiative On Classroom Practice
Contributed Paper - 30 minutes College/Univ Salon F
Presenters: **Mary Stein**, Wayne State University, Detroit, MI
John Norman, Wayne State University, Detroit, MI
Presider: **Iris Riggs**, California State University, San Bernardino, CA
The process of encouraging and implementing constructivist teaching practices in urban classrooms through the development of "learning communities' and the systemic evaluation designed to measure changes will be described.

707 "Technological Literacy" For Science Teachers: Towards a Theoretical Grounding Which Holds Up in Practice
Panel - 60 minutes General Caprice 2
Presenters: **David Jackson**, University of Georgia, Athens, GA
Bill Baird, Auburn University, Auburn, AL
Joseph Peters, University of West Florida, Pensacola, FL
Presider: **B. Patricia Patterson**, Wesley College, Dover, DE
This interactive panel discussion will address issues of science teacher preparation and professional development specific to computers and telecommunications, especially the development of a "big picture" conceptual view.

708 Trends Found in Teachers' Beliefs Regarding Science Reform
Panel - 60 minutes General Salon D
Presenters: **Jodi J. Haney**, Bowling Green State University, Bowling Green, OH
Julia McArthur, Bowling Green State University, Bowling Green, OH
Charlene Czerniak, University of Toledo, Toledo, OH
Andrew Lumpe, Southern Illinois University, Carbondale, IL
Presider: **Paul B. Otto**, University of South Dakota, Vermillion, SD
We will share and discuss recent trends found in teachers' beliefs regarding national science reform recommendations.

SATURDAY 11:15 A.M. - 12:15 P.M.

801 Contemplating the Systemic Nature of Science Education Reform: Science Teaching Practices as 'Cultural Productions'
Panel - 60 minutes General Caprice 3
Presenters: **Sherry Nichols**, University of Texas at Austin, Austin, TX
Deborah Tippins, University of Georgia, Athens, GA
Michalinos Zembylas, University of Illinois at Urbana-Champaign, Champaign, IL
Jo Ann McDonald, University of Texas at Austin, Austin, TX
Robert McDonald, Southwest Texas State University, San Marcos, TX
Presider: **James Ellis**, The National Science Foundation, Arlington, VA
Panel will present examples of research and curricular resources related to the central theme of this session — 'cultural production' and science teaching.

802A Systemic Reform Evaluation: Gender Differences in Student Attitudes Toward Science and Mathematics.
Contributed paper - 15 minutes General Caprice 1
Presenters: **Kunimitsu Kanai**, Wayne State University, Detroit, MI
John Norman, Wayne State University, Detroit, MI
Presider: **James Rye**, West Virginia University, Morgantown, WV
An analysis to determine how students attitudes differ for gender and for subject area (science and math) for each of the elementary, middle, and high school as well as across these levels.

802B A Head Start On Science

Contributed paper - 15 minutes General Caprice 1
Presenter: **William C. Ritz**, California State University, Long Beach, Long Beach, CA
Presider: **James Rye**, West Virginia University, Morgantown, WV

An overview of a project at CSULB in which science activities are being developed for Head Start youngsters (about age 4). During summer 1996, workshops for over 100 Head Start teachers and teacher aides will be conducted. What is the best way to prepare Head Start personnel to help youngsters nurture and enhance their innate "sense of wonder?"

802C Science Education Reform in a Rural County

Contributed paper - 15 minutes General Caprice 1
Presenters: **William R. Veal**, University of Georgia, Athens, GA
Tom Elliott, University of Georgia, Athens, GA
Presider: **James Rye**, West Virginia University, Morgantown, WV

This paper describes how a committee of science teachers came to understand and implement national and state standards into a science curriculum 'materials selection criteria' list.

803 A Challenging Dialogue and Critical Discourse

Panel - 60minutes General Caprice 2
Presenter: **Patricia E. Simmons**, University of Georgia, Athens, GA
Presider: **John Settlage**, Cleveland State University, Cleveland, OH

Come participate in a challenging discussion about the issues of reform.

804 Video Case Studies in Science Education

Panel - 60 minutes General Salon F
Presenter: **Nancy Finkelstein**, Harvard-Smithsonian Center for Astrophysics,Cambridge, MA
Presider: **Bob Rivers**, Purdue University Calumet, Hammond, IN

This presentation will focus on a project that is creating a series of 25 video case studies in science education for K-8 preservice and inservice teacher education.

805A Assessing Preservice Middle Grades Teachers' Understanding of Concepts in Physical Science: An Exploratory Case Study of Conceptual Change

Contributed paper - 15 minutes Middle/College/General Salon B
Presenters: **Katherine Wieseman**, University of Georgia, Athens, GA
Darwin Smith, University of Georgia, Athens, GA
Presider: **Molly Weinburgh**, Georgia State University, Atlanta, GA

Using an interactive format, we present an exploratory study of the extent of change in students' explanations for physics concepts, as revealed through an innovative approach to assessment.

805B Gender Equity in Elementary Science Textbooks: Action Research -Analysis From Preservice Elementary Teachers

Contributed Paper - 30 minutes Elementary Salon B
Presenters: **Laura Downey-Skochdopole**, Kansas State University,Manhattan, KS
M. Jenice French, Kansas State University,Manhattan, KS
Presider: **Molly Weinburgh**, Georgia State University, Atlanta, GA

This presentation highlights preservice elementary teachers development of criteria for assessing gender bias in elementary science textbooks exploring alternative ways of conducting research within the classroom context, and an analysis of their methodologies and perceptions as they engage in this process.

806A Common Ground: Interdisciplinary Collaboration in Science, Science Education & Technology

Contributed Paper - 30 minutes College/General Salon G
Presenters: **Angelo Collins**, Vanderbilt University, Nashville, TN
Lynne Barrow, Vanderbilt University, Nashville, TN
Amy Palmeri,Vanderbilt University, Nashville, TN
Jan Altman, Vanderbilt University, Nashville, TN
Todd Gary,Vanderbilt University, Nashville, TN
Marcy Singer-Gabella, Vanderbilt University, Nashville, TN
Presider: **Meta Van Sickle**, University of Charleston, Charleston, SC

This naturalistic study of an integrated course including science, education and technology focuses on the strength of commitment to students and tension from differing assessment beliefs.

806B Enhancing Undergraduate Science Instruction With Science TA/Science Education Partnerships

Contributed Paper - 30 minutes College,Univ Salon G
Presenters: **William F. McComas**,University of Southern California, Los Angeles, CA
Anne Marshall Cox, University of Southern California, Los Angeles, CA
Presider: **Meta Van Sickle**, University of Charleston, Charleston, SC

We present strategy coupling science education graduate students with science teaching assistants to enhance undergraduate science instruction and provide leadership opportunities for the science educators.

807A Mr. Reinkens' Neighborhood: Can You Say 'Conceptual Change?'

Contributed Paper - 30 minutes Elementary/College Rosewood
Presenters: **Valarie L. Dickinson**, Oregon State University, Corvallis, OR
Kirk A. Reinkens, Washington State University, Richland, WA
Presider: **Andrew Lumpe**, Southern Illinois University, Carbondale, IL

Describes research results of a preservice elementary teacher's attempt to influence conceptual change using his own teacher-developed methods.

807B Further Development of a Comprehensive Undergraduate Science Education Program for Elementary and Middle School Teachers

Contributed Paper - 30 minutes General Rosewood
Presenters: **Linda Ramey-Gassert**, Wright State University, Dayton, OH
James Tomlin, Wright State University, Dayton, OH
Beth Basista, Wright State University, Dayton, OH
William Slattery, Wright State University, Dayton, OH
Presider: **Andrew Lumpe**, Southern Illinois University, Carbondale, IL

This session will focus on the development of a specially designed comprehensive science program for preservice teachers. Preliminary results will be presented and discussed.

808A STEBI-A: A Predictive Instrument for Identifying Teachers Who Will Use Inquiry Learning in Teaching Elementary School Science

Contributed Paper - 30 minutes General Salon D
Presenters: **Virginia Marion**, Ursuline College, Pepper Pike, OH
Kathleen Sparrow, Akron Public School, Akron, OH
Isadore Newman, the University of Akron, Akron, OH
Presider: **Melissa A. Warden**, Ball State University, Muncie, IN

Results of STEBI-A, a measurement of science teaching efficacy, from a teachers' inservice program will be shared to further validate the usefulness of this instrument.

808B An Instrument For Measuring Science Teachers' Beliefs About Constructivist Teaching

Contributed Paper - 30 minutes General Salon D
Presenters: **Gary F. Varrella**, University of Iowa, Iowa City, IA
Judith Burry-Stock, University of Alabama, Tuscaloosa, AL
Presider: **Melissa A. Warden**, Ball State University, Muncie, IN

This discussion will feature a newly developed rubric designed to assess teachers' beliefs related to constructivist teaching. Applications, statistical considerations, and the rubric will be included.

LUNCH 12:30 P.M. - 2:30 P.M. AETS Business Meeting

SATURDAY 2:45 P.M. - 3:45 P.M.

901-1 Preparing Elementary Preservice Teachers in a Professional Development School; Development of Their Beliefs and Strategies for Teaching Science

Poster College/Univ Rosewood
Presenter: **Diane Sopko Adoue**, Texas A & M University, College Station, TX

This study explores the complex interrelationships within the culture of the Professional Development School and the development of science teaching practices that can be identified by the university students who participated.

901-2 Excerpts From Two Prospective Teachers' Interviews With Scientists
Poster College/Univ Rosewood
Presenter: **M.O. Thirunarayanan**, Rowan College, Glassboro, NJ
The proposed poster session will present excerpts from two prospective teachers' interviews with scientists.

901-3 The Nature and Nurture of Teachers' Brains
Poster General Rosewood
Presenter: **Deborah L. Jensen**, Texas A&M University, College Station, TX
This is the decade of the brain — but what is known about the neurocognition of teachers? This illustrates some important issues for the development of teachers' "wetware." Poster presentation

901-4 Exploring the Use of Visual Learning Logs in Elementary Science Methods Class
Poster Elementary Rosewood
Presenter: **E. Barbara Klemm**, University of Hawaii, Honolulu, HI
Marie K. Iding, University of Hawaii, Honolulu, HI
An exploration in visual literacy using visual learning logs (free-form drawings or pictograms) by preservice elementary teachers to enhance science teaching and learning.

901-5 Constructivist Teaching Practices: Perceptions of Teachers and Students
Poster General Rosewood
Presenter: **Sandra Moussiaux**, Fountain School, Roseville, MI
John T. Norman, Wayne State University, Detroit, MI
As part of district-wide systemic reform process, teachers and students were surveyed about the frequency of use of constructivist science teaching practices.

901-6 Developing Naturalistic Knowing: Teaching and Learning in Science
Poster General Rosewood
Presenter: **Diann Musial**, Northern Illinois University, St. Charles, IL
Elizabeth Hammerman, Northern Illinois University, St. Charles, IL
This paper explores a potentially powerful construct - naturalistic ways of knowing. Rooted in divergent lines of research, the construct engenders lively discussion about science education.

901-7 Changing Assessment Practices: Using Portfolios to Assess Learning In Science
Poster High Rosewood
Presenter: **Starlin D. Weaver**, Virginia Tech, Blacksburg, VA
This qualitative study was conducted to determine how a school defines and implements a new program of portfolio assessment.

901-8 Interacting with Current NASA Missions Brings Life to all Subject Areas
Poster General Rosewood
Presenter: **Jim Fitzgerald, NASA**
Current NASA Missions provide cutting edge unique opportunities for educators to interact with those involved in the missions. "Live From Mars" being one example.

901-9 Change: It's In The Works
Poster General Rosewood
Presenter: **Joneen Hueni**, Texas A&M University, College Station, TX
Caroline Beller,Texas A&M University, College Station, TX
In order to explore teacher attitudes toward change, teachers have been surveyed, observed, and interviewed. This is what the teachers have to say about change.

901-10 The Texas Alliance Online School and Online Inservice
Poster General Rosewood
Presenter: **Robert K. James**, Texas A&M University, College Station, TX
Deborah L. Jensen, Texas A&M University, College Station, TX
Have you found surfing the Internet fun, but not always useful? The Texas Alliance will demonstrate a site for teacher development that provides ongoing staff development for science teachers.

901-11 Fifth Grade Students' Perceptions About Scientists and About How They Study and Use Science

Poster	Elementary	Rosewood

Presenter: **Charles R. Barman**, Indiana University, Indianapolis, IN
Karen L. Ostland, Indiana University, Indianapolis, IN
Cindy C. Gatto, Indiana University, Indianapolis, IN
Mimi Halferty, Indiana University, Indianapolis, IN

This presentation will detail the interview protocol and analysis techniques used to obtain students' views about scientists and their perceptions about how they study and use science.

901-12 Careful Measurement and Evaluating Aspects of Systic Reform

Poster	College/Supervision/General	Rosewood

Presenter: **William Boone**, Indiana University, Bloomington, IN
Steve Rogg, Miami University, Oxford, OH

Evaluating system reform and implications for science teachers is dependant upon robust evaluation. We will discuss issues of missing data and how best to alter instruments during a reform effort.

901-13 Math and Science on TV

Poster	General	Rosewood

Presenter: **Nancy Finkelstein**, Harvard-Smithsonian Center for Astrophysics, Cambridge MA

This session will present a project that is launching a Television/Web Service for k-12 math and science education. The satellite television service and companion World Wide Web site for teachers, schools, and communities will offer extensive math and science educational media at no cost to the viewing audience.

901-14 The Private Universe Project

Poster	General	Rosewood

Presenter: **Nancy Finkelstein**, Harvard-Smithsonian Center for astrophysics, Cambridge MA

This session highlights a project which has created a series for public broadcast that examines the current research on how children learn science and implications for the classroom.

901-15 Writing-to-Learn in the Science Classroom

Poster	Elementary/Middle/High	Rosewood

Presenter: **Becky Monhardt**, Utah State University, Logan, Utah

Strategies for integrating writing-to-learn in science classrooms will be presented. The session will focus on the kinds of informal writing that will promote learning.

901-16 Resources for Science Literacy: Professional Development

Poster	General

Participants will try out Project 2061's procedure for analyzing curriculum resources and materials in light of science literacy goals such as benchmarks and standards.

901-17 Evolution in Thought and Action In Teacher Education Courses

Poster	College	Rosewood

Presenter: **Helen Parke**, East Carolina University, Greenville, NC
Jon Pedersen, East Carolina University, NC

Internal and external factors influence the design of preservice elementary and middle grades courses. This presentation focuses on the tension among the culture of the university, national level reform, and the philosophical orientation of professors.

902 University Grant Projects on Science Education for Students with Disabilities

Panel - 60 minutes	General	Caprice 2

Presenters: **Katherine I. Norman**, Cal State San Marcos, San Marcos, CA
Diana Hunn, University of Dayton, Dayton, OH
Kevin Finson, Western Illinois University, Macomb, IL
Greg Stefanich, University of Northern Iowa, Cedar Falls, IA
Presider: **Katherine I. Norman**, Cal State San Marcos, San Marcos, CA

Presenters from four states across the U.S. will describe grant projects designed to prepare teachers to teach science to students disabilities in inclusive settings.

903A Knowledge and Incidence of Domestic Violence Among Elementary Science Methods Students

Contributed paper - 15 minutes General Caprice 3

Presenter: **Claudia T. Melear**, University of Tennessee, Knoxville, TN

Presider: **Joe Engemann**, Brock University, St. Catharines, Ontario

Twice the national average (CDC, 1996) among 40 preservice teacher education students report they have experienced domestic violence. As an issue of women's health and because most teachers are women, since education research is needed in this area.

903B Influence of Classroom Visits Upon the Participants

Contributed paper - 15 minutes General Caprice 3

Presenters: **Matthew Teare**, Cleveland State University, Cleveland, OH
John Settlage, Cleveland State University, Cleveland, OH

Presider: **Joe Engemann**, Brock University, St. Catharines, Ontario

Within an elementary science methods course, students visited select classrooms in threesomes. We will report on the impact upon the visitors and their hosts.

904 The Integrated Science Curriculum Development Matrix: A Tool for Reform

Demonstration - 60 minutes General Salon B

Presenter: **Sandra Johnson**, Education Service Center, RegXIII, Austin, TX

Presider: **James P. Barufaldi**, University of Texas at Austin, Austin, TX

The purpose of this session is to demonstrate the use of *The Integrated Science Curriculum Matrix* for planning integrated thematic science.

905 Facing the Challenges: Further Discussion of the Factors Influencing Successful Implementation of an Effective Science Program in Professional Development Schools

Panel - 60 minutes General Salon G

Presenters: **Christine Ebert**, University of South Carolina, Columbia, SC
Linda Ramey-Gassert, Wright State University, Dayton, OH
Gail Shroyer, Kansas State University, Manhattan, KS
Kenneth Schoon, Indiana University NW, Gary, IN

Presider: **James Tomlin**, Wright State University, Dayton, OH

Science educators from three state universities and teachers from PDS partner schools will share their insights and lessons learned about enhancing science education.

906 Combining Cooperative Learning, a Learning Cycle, and a Constructivist Approach to Teach Science Process Skills

Hands On Workshop 60 minutes General Salon D

Presenter: **Cliff Schrader**, Summit County Educational Service Center, Cuyahoga Falls, OH

Presider: **Juanita Jo Matkins**, Louisa, VA

Participants will be engaged in an activity which will allow them to explore and cooperatively construct an explanation of several science concepts. The concepts constructed will be extended to account for other events and then the learning will be evaluated.

907A Inquiry in a Science Course for Preservice Elementary Teachers

Contributed Paper - 30 minutes College/Univ Caprice 1

Presenter: **Anita Roychoudhury**, Miami University, Hamilton, OH

Presider: **Bruce Munson**, University of Minnesota, Duluth, MN

Changes in students' thinking and their views about inquiry-based learning in the context of a weather-project in a physical science content course will be presented.

907B Systemic Reform in Texas: Role of Teachers and Science Educators in Restructuring the Science Preparation of Elementary Teachers

Contributed Paper - 30 minutes College/Univ Caprice 1

Presenter: **Carol L. Stuessy**, Texas A&M University, College Station, TX

Presider: **Bruce Munson**, University of Minnesota, Duluth, MN

Describes the model and efforts of the Texas SSI to involve teachers and science educators in restructuring elementary science preparation at the state level.

908A Perspectives on the Use of Video Based Case Studies in Teacher Preparation

Contributed Paper - 30 minutes College/Univ Salon F

Presenter: **Clifford A. Hofwolt**, Vanderbilt University, Nashville, TN

Presider: **Richard Pontius**, SUNY-Plattsburg, Plattsburg, NY

Discussion of the design of information "rich" video-based case studies and how these can be used with prospective science teachers.

908B Teaching Teachers To Teach Technology Through TIES

Contributed Paper - 30 minutes Elementary Salon F

Presenters: **Walter S. Smith**, University of Akron, Akron, OH
Kathy Sparrow, Akron Public Schools, Akron, OH
Rose Heintz, Inventure Place, Akron, OH
Carole Newman, University of Akron, Akron, OH

Presider: **Richard Pontius**, SUNY-Plattsburg, Plattsburg, NY

Through Technology and Invention in Elementary Schools (TIES) teachers of African Americans and Native Americans in grades 3-6 learn to incorporate technology in science teaching.

SATURDAY 4:00 P.M. - 5:00 P.M.

1001 Undergraduate and Graduate Courses and Programs on Science Teaching and Inclusion

Panel - 60 minutes General Caprice 2

Presenters: **Helen Parke**, East Carolina State University, Greenville, NC
Sally Mayberry, St. Thomas University, Miami, FL
M. Virginia Epps, University of Wisconsin - Whitewater, Whitewater, WI
Paula Neville, University of Wisconsin - Whitewater, Whitewater, WI

Presider: **Katherine I. Norman**, Cal State University - San Marcos, San Marcos, CA

Science education in inclusive environments is the focus of this panel presentation on innovative courses and programs at universities in Wisconsin, Florida and North Carolina.

1002A Mentoring the Beginning Science Teacher: Facilitating the Development of a Reflective Practitioner

Contributed Paper - 15 minutes General Caprice 3

Presenters: **Jeanie Roberson**, Vanderbilt University, Nashville, TN
Margaret W. Smithey, Vanderbilt University, Nashville, TN

Presider: **Joan M. Whitworth**, Morehead State University, Morehead, KY

This paper describes the results of an ethnographic study designed to document how a mentor facilitates the "learning to teach process" of a beginning teacher.

1002B Alternative Assessment in a Ninth Grade Biology Classroom: A Teacher's Description of His 30 Years of Assessment Change

Contributed Paper - 15 minutes Middle/High/College Caprice 3

Presenter: **Peter Veronesi**, SUNY College at Brockport, Brockport, NY

Presider: **Joan M. Whitworth**, Morehead State University, Morehead, KY

The past decade has brought forth enormous calls for more meaningful assessment. Hear rationale and perceptions of one biology teacher attempting to use alternative assessment.

1002C Metacognitive Tools In Art and Science

Contributed Paper - 15 minutes College/Univ Caprice 3

Presenter: **Mike Neslon**, University of Wisconsin - Whitewater, Whitewater, WI

Presider: **Joan M. Whitworth**, Morehead State University, Morehead, KY

Visual imagery was used to engage teachers in dialogue about perceptions, interpretations, and narrations. Journal entries will be used to discuss the metacognitive tools employed.

1003A Inquiry Science Teaching in the Urban Setting

Contributed Paper - 30 minutes College/Univ Caprice 1

Presenters: **Richard Fairman**, Miami University, Oxford, OH
Bruce Perry, Miami University, Oxford, OH

Presider: **Judy Beck**, University of Wisconsin - LaCrosse, LaCrosse, WI

This study describes how inquiry based science education is perceived by secondary teachers practicing in predominately minority educational environments.

1003B The Behaviors & Beliefs of an Exemplary Urban Science Teacher

Contributed Paper - 30 minutes College/Univ Caprice 1

Presenter: **Alan Colburn**, Cal. State Long Beach, Long Beach, CA

Presider: **Judy Beck**, University of Wisconsin - LaCrosse, LaCrosse, WI

How does a superstar teacher apply constructivist practices in a crowded and diverse urban classroom? Results of this case study shed light on the problem.

1004A Performance Assessment for Preservice Elementary Teachers: Is It Worth the Effort?

Contributed Paper - 30 minutes College/Univ Salon F

Presenters: **Mark D. Guy**, University of North Dakota, Grand Forks, ND
Jackie Wilcox, University of North Dakota, Grand Forks, ND

Presider: **Fouad Abd-el-khalick**, Oregon State University, Corvallis, OR

Student and instructor perspectives on a performance assessment component of an elementary science methods course are presented in light of current assessment reform recommendations.

1004B Socialization Influences on Elementary Teachers Prepared in an Innovative Teacher Education Program: A Longitudinal Study

Contributed Paper - 30 minutes College/Univ Salon F

Presenters: **Margaret E. Bolick**, Kansas State University, Manhattan, KS
M. Gail Shroyer, Kansas State University, Manhattan, KS
Emmett L. Wright, Kansas State University, Manhattan, KS
Heidi Gruner, Kansas State University, Manhattan, KS

Presider: **Fouad Abd-el-khalick**, Oregon State University, Corvallis, OR

This longitudinal study examines the impact of the restructuring of a teacher education program and the influence of socialization within the school culture on beginning teachers.

1005A A Detailed Description of a Suburban Ohio Board of Regents Eisenhower Program for the Reform K-5 Elementary Science Including Participant Cognitive and Attitude Testing

Contributed Paper - 30 minutes Elementary/College/Supervisor Salon B

Presenter: **Ed Jones**, Miami University, Oxford, OH

Presider: **Raymond Francis**, Appalachia Educational Laboratory, Charleston, WV

A detailed description of a suburban Ohio Board of Regents Eisenhower Program for the reform of K-5 elementary science including participant cognitive and attitude testing.

1005B Key Articles and Experiences for Students Developing a Researched-Based Framework for Teaching Science

Contributed Paper - 30 minutes General Salon B

Presenters: **Michael Clough,** Memorial High School, Eau Claire, WI
Craig Berg, UW-Milwaukee, MilwauKee, WI

Presider: **Raymond Francis**, Appalachia Educational Laboratory, Charleston, WV

We will suggest some basic elements that make-up a research-based framework for teaching science, followed by a list of key experiences and articles to help teachers develop this framework

1006A Business and Industry Awareness Project

Contributed Paper - 30 minutes General Salon G

Presenter: **Tracy J. Posnanski**, University of Wisconsin -Milwaukee, Milwaukee, WI

Presider: **Lucille Slinger**, University of Wisconsin-LaCrosse, LaCrosse, WI

An overview of a math/science teacher summer internship program. Teachers participate in internship positions at local business/industries and develop curricular units, in conjunction with university course work, based on their internship experience.

1006B Scientist's Perception of Scientific Knowledge

Contributed Paper - 30 minutes General Salon G

Presenter: **Michael Hughes**, Emory University, Atlanta, GA

Presider: **Lucille Slinger**, University of Wisconsin-LaCrosse, LaCrosse, WI

A consensus model of scientific knowledge based on scientists' perceptions is presented. Differences in scientists' view across disciplines and gender are reported.

1007 A Masters Program That Builds Science Leaders in Elementary Schools
Hands-on-Workshop - 60 minutes Elementary/College Salon D
Presenter: **Paul C. Jablon**, Brooklyn College, Brooklyn, NY
Presider: **Steven Gilbert**, Indiana University -Kokomo, Kokomo, IN
What is needed in a masters program for elementary teachers who want to focus on science and environmental education.

1008 Thinking Like a Teacher.. a Conversation On Considering the Professional Development of Science Teacher Educators Within a Climate of Reform
Panel - 60 minutes College/Supervisor/General Rosewood
Presenters: **Deborah Tippins**, University of Georgia, Athens, GA
Sherry Nichols, University of Texas, Austin, TX
John Staver, Kansas State University, Manhattan, KS
Sandy Abell, Purdue University, West Lafayette, IN
David Jackson, University of Georgia, Athens, GA
William Veal, University of Georgia, Athens, GA
Katherine Weiseman,
Presider: **Hans O. Andersen**, Indiana University, Bloomington, IN
This interactive panel session will highlight important "questions we need to ask" when considering the professional development of science teacher educators in a climate of reform.

SATURDAY 5:15 P.M.-6:30 P.M.

Special Session: Implications of the NSES for Preservice Elementary Science Methods Rosewood
Presenters: **Helen Park**, East Carolina University, Greenville, NC
Jim Shymansky, University of Iowa, Iowa City, IA
Larry Yore, University of Victoria, Victoria, BC, Canada
A discussion of responses to a survey of AETS meeting participants on alternative methods and materials for preservice elementary science methods instruction in light of recommendations in the NRC Standards. Participants planning to attend this session should complete and return the survey at the registration desk prior to the session

SUNDAY 9:00A.M. - 10:00 A.M.

1101 An Overview of NSF Programs for Teacher Preparation and Teacher Enhancement
Panel General Caprice 1
Presenter: **Jim Ellis**, National Science Foundation, Arlington VA
Terry Woodin, National Science Foundation, Arlington VA
Presider: **Peter Rubba**, Penn State University, University Park, PA
NSF program directors will describe program priorities, deadlines, process of proposal submission, review, and decision making, and elements of successful proposals.

1102 What Teachers Are Telling Us About Reform: Implications for Teacher Education
Panel General Caprice 2
Presenters: **Joan M. Whitworth**, Morehead State University, Morehead, Ky
Kathleen S. Davis, University of Nevada Las Vegas, Las Vegas, Nevada
Presider: **Kathryn Powell**, TexasA & M, Bryan, TX
Three research studies of science education reform efforts provide teacher educators with factors to consider in order to support teachers' learning of innovative teaching practices.

1103 Activity Based Science for K-8 Methods
Hands-on-workshop(60minutes) Elementary/Middle/College Rosewood
Presenters: **Helen Parke**, East Carolina University, Greenville, NC
Jim Shymansky, University of Iowa, Iowa City, IA
Larry Yore, University of Victoria, Saanichton, BC, Canada
Presider: **Michael Grote**, Ohio Wesylan University, Delaware, OH
This program will actively involve participants in the ABK-8 program which is a hands-on , modular science methods program connecting theory and practice. Each module Contains materials developed by master teachers and science educators.

SUNDAY WORKSHOPS January 12, 1997

Workshop participants must pick-up their tickets at the registration counter. Participants of Workshops C and D should meet at the 5th Street entrance for departure.

A. Constructing Comprehensive Assessment Systems ***Salon D***

The workshop will focus on using appropriate assessment technologies including selected response, extended response, performance assessments, and portfolio strategies for college students. These strategies and materials are products of the SCASS Science Assessment Project. SCASS is the State Collaborative Assessment Student Standards Project which is a 15 state collaborative to produce quality science assessment technologies K-15. Join us for a hands-on session which will include a variety of authentic assessments. Limited to 40 participants.

Presenter: Charles R. Doyle-Warren ***Sunday 9:00-11:00***

B. Portfolios: A Tool for Science Assessment ***Salon B***

Participants will be introduced to a system of science portfolios that has been developed with collaboration of various states and the SCASS project sponsored by the Council of State School Officers (CCSSO). The workshop will focus on the various components of a science portfolio, scoring criteria, and a scoring rubric appropriate for various grade levels. The role of higher education faculty will be discussed in making this a part of preservice and inservice education efforts in their states. Limited to 40 participants.

Presenters: Piyush Swami and Stan Santilli ***Sunday 9:00-11:00***

C. Using the Internet to Support Science Teacher Preparation ***University of Cincinnati***

Participants will use the computers in a lab at the College of Education on the University of Cincinnati campus to access and review selected resources on the World Wide Web that relate to science teacher education. Strategies for using the Netscape browser will be recommended. Each participant will receive a disk that includes bookmarks to recommended web sites. Limited to 20 participants.

Presenter: Glenn Markle ***Sunday 8:30-12:00 (includes travel time)***

D. Technology in Science Teacher Education: Producing Your Own Electronic Media ***University of Cincinnati***

A team of science educators at the University of Cincinnati will demonstrate the production of electronic media that is used to support science teacher preparation. Substantive questions about the uses of electronic media in teacher education programs and technical questions about the production of CD ROMS will be addressed. The workshop will take place on the University of Cincinnati campus and is limited to 20 participants.

Presenters: Ted Fowler, Manisha Sharma, and Theresa Orloff ***Sunday 8:30-12:00 (includes travel time)***

E. Teaching Physics and Chemistry with Toys ***Caprice 1***

For years, teachers from far and near have been attending the Toys with Science Program, an NSF funded workshop conducted by physics and chemistry faculty from Miami University. In the physics portion of this workshop, ideas for teaching energy and motion with toys will be presented. In the chemistry portion, the activities will include pure substances and mixtures.

Presenters: Beverley A. P. Taylor and John Williams ***Sunday 9:00-11:00***

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AETS AWARDS

Award I:
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by Lawrence Scharmann of Kansas State University
1995 Using Visits to Interactive Science and Technology Centers, Museums, Aquaria, and Zoos to Promote Learning in Science
by Leonie Rennie and Terrence McClafferty
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by Larry Scharrnan and Ann Stanheim-Smith of Kansas State University
1997 Empowering Science Teachers: A Model for Professional Development
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1980
Anton Lawson, Arizona State University
1983
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1985
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1986
Charles R. Coble, East Carolina University
1987
John Penick, The University of Iowa
1988
James Barufaldi, University of Texas
1989
Lawrence F. Lowery, University of California
1990
William C. Kyle Jr., Purdue University
1991
Barry Fraser, Curtin University of Technology, Australia
1993
Cheryl Mason, San Diego State University
1994
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1997
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Tufts University

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Ohio State University

AWARD IV:
INNOVATION IN TEACHING SCIENCE TEACHERS

1990	A Reflective Approach to Science Methods Courses for Preservice Elementary Teachers by Dorothy Rosenthal of California State University, Long Beach
1991	Enhancing Science and Mathematics Teaching by Kenneth Tobin, Nancy Davis, Kenneth Shaw, and Elizabeth Jakubowski of Florida State University
1992	The Learning Cycle as a Model for the Design of Science Teacher Preservice and Inservice Education by Peter Rubba of Pennsylvania State University
1993	Reconstructing Science Teacher Education Within Communities of Learners by Deborah Tippins, University of Georgia; Ken Tobin and Sherry Nichols, Florida State University
1995	Science for Early Adolescence Teachers (Science FEAT) A Program for Research and Learning by Samuel Spiegel, Angelo Collins, and Penny Gilmer of Florida State University
1996	An Innovative Model for Collaborative Reform in Elementary School Science Teaching by M. Gail Shroyer, Emmett Wright, and Linda Ramey-Gassert of Kansas State University
1997	Reconceptualizing the Elementary Science Methods Course Using a Reflective Orientation by Sandra Abell and Lynn Bryan of Purdue University

AWARD V:
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Papers presented at and summaries of presentations made at the 1997 AETS Annual Meeting in Seattle can be submitted for inclusion in the Conference Proceedings. The Conference Proceedings will serve as a record of the AETS Annual Meeting. It will be published as an ERIC document through the ERIC Clearinghouse for Science, Mathematics and Environmental Education. Microfiche and hard copies of the Proceedings will be available through the Clearinghouse, as are all other ERIC documents.

The 1997 AETS Conference Proceedings will be edited by Peter A. Rubba, Patricia F. Keig and James A. Rye.

Please note that papers presented at and summaries of presentations made at the 1997 AETS Annual Meeting may be submitted for inclusion in the Conference Proceedings in one of two ways: by dropping three copies in a box at the registration table at the 1997 AETS Annual Meeting, or by sending three copies to the first editor (Rubba) so they arrive within 30 days following the meeting.

PLEASE NOTE:

a) The name, address, phone and FAX numbers, and e-mail address of the submitting author should appear on a cover page (information on other authors also may appear) and

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1997 AETS Conference Papers and Presentation Summaries

READING-TO-LEARN AND WRITING-TO-LEARN SCIENCE ACTIVITIES FOR THE ELEMENTARY SCHOOL CLASSROOM

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Introduction

Many elementary school teachers realize that more and more hands-on activities is not the solution to unsatisfactory science literacy. The process-product debate of the 1960s reform in which alphabet science programs exclusively promoted hands-on concrete discovery activities was not successful for about 75% of elementary school teachers. The uncertainty of unstructured explorations, the discount of language in favor of sensory experiences, and the complex logistics of manipulatives and small groups stressed the culture of the generalist elementary teachers and their classroom environments.

Today, systemic reforms like Science -- Parents, Activities and Literature (Science PALs) in the Iowa City Community School District are attempting to implement science as inquiry focused on science literacy in a much more user-friendly fashion. Science literacy involves the abilities and dispositions to construct understanding; big ideas, values and informed opinions; and the communication strategies to inform and persuade others. Science PALs uses children's literature as assessment platforms and as springboards for inquiry. Furthermore, numerous connections have been made among science and the language arts.

This paper provides a theoretical framework for reading-to-learn science and writing-to-learn science; outlines applications of language arts approaches, explicit reading strategies and writing genre that enhance science learning; and describes some of the promising uses of these approaches for elementary school science teacher education. Each of these components is anchored in the National Research Council's National Science Education Standards (NRC, 1996) for teaching science, content, and professional development.

Theoretical Framework

Constructivist approaches emphasize the importance of prior knowledge, concurrent experiences, multiple information sources, social negotiations of meaning and integration of new understandings and existing knowledge networks (Shymansky, 1994). Clearly the sensory experiences and the oral language arts (talking and listening to science) are well accepted by contemporary science education (Lemke, 1990). Only recently have science educators begun to address the value of the print-based language (Santa & Alvermann, 1991; Yore, Holliday & Alvermann, 1994). This recognition in part is based on the realization that the elementary school classroom is a teaching-learning culture that emphasizes language arts, mathematics and social development and that the implementation of the current reforms needs to be anchored in a cross-curricular foundation and requires the enhancement of effective practices.

"My students can't read information books!" No where is this long-expressed cry more frequently heard than in upper elementary grades, when the emphasis clearly shifts from "learning to read" to "reading to learn." Likewise, the value of writing a list to consolidate understanding and to improve memory and the use of webbing to illustrate hidden connections and internal organization of information are well accepted in the elementary school culture. Unfortunately, the relationships between the print-based language arts and science achievement are not well established, but the available "research does not support the concocted claims that reading and writing in science naturally inhibit students' creativity, curiosity, and interest" (Holliday, 1992, p. 60). The major problem facing teacher educators is to convince prospective teachers and practicing teachers of the potential value of science reading and science writing when they have not had any experience with the integration of language arts and science and when much of the science education literature has maligned the importance of reading and writing in science classrooms while exclusively extolling the value of hands-on activities.

Reading-to-Learn Science

A teacher's knowledge about science text and science reading frequently determines whether or not print materials are used effectively. Many teachers fail to recognize the unique differences between narrative and expository text and cling to the traditional notions that meaning resides solely in the text and that readers simply extract the meaning. They unknowingly design instruction involving science as if science texts were narrative rather than expository and as if reading was a meaning- taking process rather than a meaning-making process (Digisi & Willett, 1995; Gottfried & Kyle, 1992; Shymansky, Yore & Good, 1991).

Science text, unlike the familiar content and predictable story grammar of children's literature, contains unfamiliar content and text structures, heavy conceptual demands, and unique vocabulary. The purpose of scientific text is to assist uninformed and misinformed readers construct meaning about specific science ideas using an expository approach, words (concept labels) with specific meanings, complex and interconnected sentences, and specific text structures (description, collection, compare/contrast, problem/solution, causation).

Reading is not simply a unidimensional bottom-up or top-down process involving printed symbols. Rather, reading is an interactive-constructive process that involves making meaning by negotiating understanding between the text and the reader's concurrent experiences and memories of the topic within a sociocultural context (Yore & Shymansky, 1991). The interactive-constructive model of science reading recognizes the importance of prior knowledge, strategies, metacognition (awareness and executive control of meaning making), and sociocultural context.

The interactive-constructive model discounts the beliefs that expert readers differ from novice readers simply in the number of decoding skills acquired or that meaning is simply embedded in the text. An efficient, successful science reader is a strategic person who is aware of, flexible, and manages several sources of information, science text, meaning making and the selection, use, and substitution of several strategies (Craig & Yore, 1995). Flood (1986) metaphorically described the role of printed language in the construction of understanding as the way a contractor uses blueprints in the construction of a building. Flood stated:

> Texts establish broad limits of possible meanings, but they do not specify a single meaning. Readers (not texts) create meaning through negotiations with authors. (p. 784)

Readers progressively resolve conflicting meanings involving text-based interpretations extracted from print, recalled ideas from the reader's memory, and shared ideas from the sociocultural context (Craig & Yore, 1996). The reader's recollections might involve different types of knowledge: topic, language structures, science text, and scientific enterprise (Alexander & Kulikowich, 1994). Sociocultural context includes the values, beliefs, opinions, and attitudes inherent in the learning environment.

How readers construct understanding appears to be influenced by the readers' prior knowledge, metacognitive awareness, executive control, and access to information rather than the source of information.

> To comprehend what we are taught verbally, or what we read, or what we find out by watching a demonstration or doing an experiment, we must invent a model or explanation for it that organizes the information selected from the experience in a way that makes sense to us, that fits our logic or real world experiences, or both. (Osborne & Wittrock, 1983, p. 493)

"Knowledge use and control are at the heart of the knowledge-construction process through purpose setting, planning and organizing, and constructing meaning" (Ruddell & Unrau, 1994, p. 1022).

Expert science readers have metacognitive knowledge about science reading, science text, and specific science reading strategies. Several strategies critical to constructing meaning have been identified; they are frequently absent in ineffective readers but respond to instruction (Dole, Duffy, Rochler & Pearson, 1991; Pressley, Johnson, Symons, McGoldrick & Kurita, 1989). They include:

1. Assessing the importance of text-based information and prior knowledge.
2. Generalizing questions to set purpose.
3. Summarizing.
4. Inferring meaning.
5. Monitoring comprehension.
6. Utilizing text structure.
7. Reading and reasoning critically.
8. Improving memory.
9. Self-regulating to fix-up comprehension failures.
10. Skimming, elaborating, and sequencing.

Older and better readers conceptualize reading and these strategies differently from younger and less able readers. Baker (1991) pointed out that able readers recognize that reading is about understanding and that strategies change to match purpose, utilize various standards to evaluate comprehension, and apply different strategies to fix-up comprehension failures. Effective readers have knowledge about the reading process and personally regulate their purpose, effort, and approach while they are reading.

Explicit instruction on science reading strategies improves metacognitive awareness, reading comprehension, and science achievement (Holden, 1996; Spence, 1994). If it is to be successful, explicit instruction must address all parts of metacognition. Jacobs and Paris (1987) subdivided the metacognitive knowledge (self-appraisal) into declarative knowledge (what), procedural knowledge (how), and conditional knowledge (why and when). They subdivided control (self-management) into strategic planning, monitoring progress, and self-regulation. Pearson and Dole (1987) provided guidelines for effective comprehension instruction that develops metacognitive awareness and transfers knowledge into action. They suggest explicit instruction needs to be embedded in a natural context setting and that instruction should systematically establish need, model desired outcome, provide direct practice and consolidation, and encourage transfer of ownership and application.

Writing-to Learn-Science

"Writing-to-learn involves and emphasizes the powerful role language plays in the production, as well as the presentation of knowledge" (Connolly, 1989 p. 2). This rhetoric promotes constructivist perspectives of learning by illustrating that the symbol systems used to communicate also play a critical role in constructing meaning and by reflecting the unique way scientists communicate ideas within the scientific community. Science writing involves adopting appropriate rhetorical stances, text structures, and genres that accurately reflect scientific assumptions—such as the need for repeatability, verifiability, generalizability, and patterns of argumentation (evidence, warrants, claims).

Halliday (1993) cautioned about over-emphasizing the interpretive nature of scientific language, disregarding the unique structure-function relationship of writing, and assuming that creative and narrative writing will improve science understanding. In order to enhance science learning and improve communication with the science community discipline-specific expository and personal writing tasks must match the inquiry nature of science, the evaluative view of knowledge, and the target learning outcomes. Unfortunately, "we must persuade a group of teachers who themselves did not learn science . . . this way, that writing-to-learn is not only useful but essential for a certain type of student" (Tobias, 1989, p. 48).

Newell and Winograd (1989) stated that "there is at present only slender empirical base from which to conceptualize how writing may aid learning about the topic, that is, how the writing process and what writers take from writing are interrelated" (p. 196). However, writing science appears to clarify fuzzy thinking and enhance understanding (Fellows, 1994; Keys, 1994; Rivard, 1996). Writing makes abstract ideas permanent and allows them to be publicly analyzed, dispassionately criticized, checked for precision, verified for logic, and tested for content. Although writing is a natural extension of speaking, communicating with an unseen audience represents a significant jump in cognitive demand from face-to-face speaking with and listening to someone (Vygotsky, 1978).

Teachers need to help students move from the predominant knowledge-telling writing, which involves converting knowledge from long-term memory into written words essentially unaltered, to a knowledge-transforming approach in which knowledge is actively reworked to improve understanding—"reflected upon, revised, organized, and more richly interconnected" (Scardamalia & Bereiter, 1986, p. 16). The knowledge-transforming model clarifies the role of conceptual knowledge about the target topic and of metacognitive knowledge about discourse, patterns of argumentation, and genre. Utilizing the knowledge-transforming model as an operational framework, teachers would get students to spend more time setting purpose, specifying audience, selecting a purpose-appropriate genre, thinking, negotiating, strategic planning, reacting, reflecting, and revising. Teachers would also provide explicit instruction embedded in the authentic context of "science as inquiry" designed to clarify what writing is; the purpose-specific nature of scientific genre; the interactive, constructive, generative nature of science language; the relationship between evidence, warrants, and claims; and what, how, when, and why to use specific writing strategies. The describe, explain, instruct, and argue genre appear to have the greatest applications to science (Gallagher, Knapp & Noble, 1993).

Description involves personal, commonsense, and technical descriptions, information and scientific reports, and definitions. Frequently descriptions will be structured by time-series of events, scientifically established classifications or taxonomies, or accepted reporting pattern of information (5 Ws). Explanation involves sequencing events in temporal or causal relationships. Explanations attempt to link established ideas or models to observed effects by using a logical connective of "if this, then this." Instruction involves logical ordering a sequence of actions to specify a procedure, manual, experiments, recipe, or direction. Instructions can effectively utilize a series of steps—short declarative statements—in which the sequence is established by tested science, i.e., pour acid into water before adding zinc. Argumentation involves logical ordering or propositions to persuade someone in an essay, discussion, debate, report, or review. Arguments attempt to establish the boundaries and conditions of the issue and then to systematically discredit, destroy, or support components of the issue to clearly disconfirm or confirm the basic premises.

Howard and Barton (1986) stated the "idea is to learn to think in writing primarily for your own edification and then the eyes of others. This approach will enable you to use writing to become more intelligent to yourself—to find your meaning—as well as to communicate effectively with others" (p. 14). The following principles should guide the development of writing-to-learn tasks in science (Tchudi & Huerta, 1983):

- Keep science content central in the writing process.
- Help students structure and synthesize their knowledge.
- Provide a real audience for student writers that will value, question, and provide supportive criticism.
- Spend time prewriting, collecting information from various sources (concrete experiences, print materials, experts, electronic data banks, visuals, etc.), sharpening focus, and strategic planning.
- Provide on-going teacher support, guidance, and explicit instruction.
- Encourage revisions and redrafts based on supportive criticism to address conceptual questions and clarify understandings.
- Clarify the differences between revising and editing (format, spelling, mechanics, grammar).

Writing in science during the elementary school years has generally been used for evaluation and review purposes but not for emphasizing knowledge construction and critical thinking, and for stressing creative writing but not expository writing. Jan (1993) used implicit and explicit modelling to help students learn about the various ways language is used in science and to have students use print-based language to learn science. She stressed that writing in science "must not be relegated to mere completion of worksheets or to the recipe-type" writing tasks (p. 41).

Rather, students need to be engaged in authentic science situations that involve different writing forms for specific purposes and audiences.

Unsworth and Lockhart (1994) explored how junior primary (Grade 2) teachers attempted to integrate print-based language arts into their science classes in two inner-city schools. They found writing (12%, 17%) and reading (15%, 11%) accounted for a minority of the instructional time in the two science classes. The writing involved a variety of tasks: factual, extending text, lists, and diagrams. Unfortunately, little preparatory or explicit instruction, limited to modelling and structured worksheets, was provided for science writing and science reading.

Burkhalter (1995) used an instructional scaffolding dealing with persuasive writing (data, warrants, and claims) with grades 4 and 6 students and found significant pretest-posttest conceptual growth, a significant explicit instruction effect, and a significant gender effect favoring females. She concluded that students as young as nine years can benefit from explicit persuasive writing instruction.

Bergin (1995) explored a combined reading-writing approach to teaching summarizing. She stated:

> The cognitive operations involved in summarizing include knowing how to select, condense and transform information. Selecting information involves identifying information which is relevant and important. Condensing involves synthesizing information so that the structurally important information is gleaned; and in order to transform information, students must relate main ideas to each other and reconstruct a meaning which is concise but representative of the original text's structure and content. (p. 30)

These cognitive operations have been demonstrated to be part of an expert scientist's and science learner's repertoire. Bergin found that students improved their ability to select and combine main ideas when the instruction provided an effective framework, active role, and encouraged self-regulation and improved skills.

Children's Literature as Assessment Platforms and Springboards for Inquiry

Children's literature such as Goldilocks and the Three Bears, Porker's Taxi, The Hungry Caterpillar and Who Sank the Boat provide excellent platforms and springboards for science. Each of these stories include common misconceptions or interesting problems about thermodynamics, work and energy, life cycles, and buoyancy concepts embedded in a natural context for children.

Science PALs utilizes science-oriented children's literature as the central focus of bookbags designed to engage parents and children in an assessment of prior knowledge. The book serves as an assessment platform and a structured interview protocol consisting of 4 to 7 questions guides the parent-child discussion. The discussions are enriched by hands-on activities that have minimal equipment requirements included in the bookbag.

Parent involvement is often cited as the single best way to improve student achievement and interest in school. Consistent evidence exists to show that parent encouragement, activities and interest at home and parent participation at school affect children's achievement even after the student's ability and family socioeconomic status is taken into account. Students learn best when parents actively monitor and support their school work. In addition, students benefit from the interactions with parents and guardians provided by the hands-on science experiences, together with conversations about what is occurring.

Making parents productive partners in education benefits teachers, as well as parents and students. Science PALs teachers value parent involvement in school in both instructional and noninstructional capacities and frequently have the opportunity to communicate with parents about students and school events. Through involvement with school, parents gain first-hand information about what their child is experiencing and learning and become strong advocates for school and collaborative problem-solvers when needed.

Therefore, asking parents to play a role in gathering information about students' ideas will be viewed as important by all involved, but this task needs to provide opportunities that are welcomed by both participants and that are useful to the teacher in order to be most effective.

Requirements for the parents must take into account time constraints on the part of the parent/care giver and the teacher must be able to easily convey the purpose and expectations associated with the task to the parent. The Science PALs project has created opportunities for parent involvement that address these needs and are extremely well-received by parents and students. The purpose of collecting student information does more than give parents and children a chance to interact about what is happening at school. The information collected and reported are necessary resources for the constructivist teacher (Chidsey & Henriques, 1996).

Science PALs also use children's literature as natural context to initiate science units. Teachers read stories to get students thinking and talking about science ideas and as inquiry springboards for hands-on activities. Frequently a single story will provide numerous challenges for students to explore. Students and teachers can simply replicate the science described in the story or can design experiments or plan library research to verify the science concepts used in the story. Upon completion of the science units, students can return to the literature to critically analyze the embedded concepts and to rewrite the story to achieve scientific accuracy.

Explicit Science Reading Instruction

Explicit science reading instruction must be embedded in the natural context of effective science instruction, must provide information about why and when, as well as what and how, and must address transfer to other science reading situations (Pressley, El-Dinary, Caskins, Schuler, Bergman, Almasi & Brown, 1992). Effective explicit instruction should be embedded in authentic learning task, teachers should model desired outcome and think-aloud to make metacognition public, and students should be encouraged to do the same and encouraged to take ownership of the strategy. Transfer of ownership and application are consistently the most problematic aspects of strategy instruction, but explicit application of strategies across the curriculum and within a discipline enhances the likelihood of transfer. Furthermore, research results indicate that less able readers (low-reading-ability students and male students) benefit most from such explicit instruction and that explicit strategy instruction improves general science reading comprehension (Spence, 1994). Unfortunately, only a small percentage of elementary school students receives any explicit content reading instruction. It is not surprising that many students find reading science texts difficult and frustrating.

The following strategies address six areas of science reading comprehension that respond to strategic instruction: using surface features, prior knowledge, defining from context, identifying main ideas, summarizing, and recognizing text structures (Spence, 1994).

Surface Structure and Organization

The layout of the text, the titles of the sections, the diagrams, pictures and charts, and the questions posed in the text are surface features and organizational clues that aid readers' comprehension. These clues provide an overview of what the text is about and what some of the subtopics may be. Considerate science text provides consistent layout, logical topic development, and pictures, graphs, tables, and illustrations to enhance the meaning constructed from the printed message. Visual adjuncts are anchored in the print and are clearly labelled to enhance clarity and connectedness. Effective science text provides advance organization of units and chapters and provides concrete experience with a topic prior to most reading activities.

Prior Knowledge

Establishing experiential background and accessing prior knowledge are critical in the improvement of science reading comprehension. The abstract nature of science texts dictates that scientific materials are not to be read in isolation from other experiences and supportive activities. A simple guiding principle is "do first, read later." Traditionally, teachers and textbooks reserve concrete explorations until after students have read the text. This approach is justified for classroom management reasons, but it prevents the experiences from being utilized by students to facilitate comprehension and enrich meaning. Furthermore, this sequence relegates the explorations to verificational inquiries or cookbook activities that simply confirm what the text has stated. Reading concept-rich science material in elementary school should be utilized to confirm, reinforce, and enrich concepts partially developed by concrete inquiries and supplemented by peer pair, cooperative group, or whole class discussions.

One way to access prior knowledge, set purpose, monitor progress, and improve science reading comprehension is to use the K-W-L approach, which utilizes a three-column chart to facilitate text processing (Ogle, 1986). K-W-L charts systematically require students to establish what they know (K) about a topic, to set what they want to know (W), and to monitor what they have learned (L). The K-W-L approach is closely aligned with the metacognitive dimension of the interactive-constructive model's accessing prior knowledge, setting purpose, and monitoring progress. Classroom application of the K-W-L technique might involve brainstorming to list what is already known (K) about the topic and to elicit questions that reflect what students want (W) to know about the topic. Teachers must be careful to suspend judgment of student ideas during the initial discussions, to provide questions pertinent to the reading, and to elicit student-generated questions that maximize the students' ownership of the process. After reading the text, both scientific or issues-related discussions should help students engage prior knowledge, address contradictions, and construct new understandings, composed of either revised or new conceptions. These results are entered in the third column of the K-W-L chart. Comparing the entries in all three columns allows both the teacher and the students to clearly monitor learning (L).

Using Context

Science text is composed of unique word labels for conceptual clusters of scientific experiences that are uncommon in non-science text, and these word meanings reflect specific situational context. Effective readers frequently make decisions about word meanings based on contextual clues provided within the word, sentence, and passage surrounding the target word. The use of prefixes, suffixes, and root-words; the use of metaphors and analogies; the use of specific signal words and logical connectives; and the use of general text meaning are component skills involved in the defining from context strategy.

Identifying Main Ideas

Students who receive explicit instruction on identifying main ideas demonstrate improved comprehension (Dole, Duffy, Roehler & Pearson 1991). Paris (1987) utilized a "detective" metaphor (a reasonable metaphor for a scientist) in which the reader uses clues like pictures, topic, and title to find the main idea. He pointed out that many readers mistakenly believe the main idea is always described in the first or last sentence of the paragraph; unfortunately, science paragraphs do not always contain traditional topic sentences. Effective science readers must use a variety of relevant clues to identify main ideas or to even generate their own when none is given. The following lesson plan illustrates how elementary students might be taught about main ideas in the science classroom (Figure 1). Title, subheadings, bold-print, margin notes, pictures, in-text questions, topical context, and other print and layout features can be used as clues to imply main ideas. The actual clue used may vary from text to text.

Summarization

Ineffective readers tend not to differentiate amongst information and often "tell all" when asked to summarize. This weakness may be apparent in these students' class notes and highlighted textbooks; notes resemble verbatim minutes and textbook pages look like fields of dandelions. Explicit instruction on selecting important information, deleting that which is less important, trivial or redundant, and synthesizing the retained information into an integrated, coherent, and accurate representation improves comprehension (Dole, et al, 1991).

With slight modifications of Paris' (1987) "western round-up" metaphor, readers' attention can be refocussed from the 5 W's for current events to main ideas, applications, evidence and exceptions for generating science text summaries. Other metaphors can be developed to capture regional differences and student's interests, such as seine fishing, etc. Macro-rules can be established to get students to identify important main ideas, to delete unnecessary details and identify critical evidence and examples/counter-examples, and to generate a concise paragraph or pattern of argumentation that retains the author's intent. The following example demonstrates a practical application of explicit instruction utilizing a typical science textbook (Figure 2).

Text Structures

Expository text does not have a single developmental structure like the traditional narrative text's story grammar (setting, beginning, development, ending). Science texts frequently utilize five common

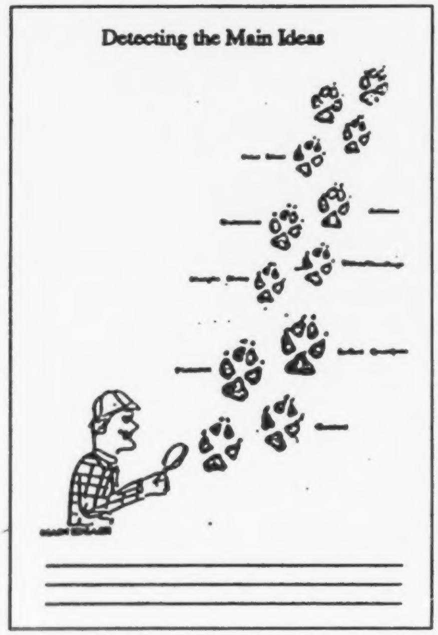
Figure 1
Explicit Instruction about Detecting the Main Ideas

1. Understanding the Metaphor

   The teacher, wearing a deerstalker hat, tweed jacket with large magnifying glass, referring to a poster of labeled footprints (pictures, margin notes, titles/ headings, context, prior ideas, actions, in-text questions, outcomes) accompanied by two questions, discusses with the class how clues are used to infer "who done it?" and "what caused it?" A review of how to play *Clue* © (Parker Brothers) illustrates how they used evidence to eliminate possibilities and progressively arrive at the best option. Attention is then directed toward the metaphor on the poster and the two questions:
   1. Did I ask myself questions?
   2. Did I use clues to find the main idea?

2. Direct Explanation

   Students are asked to explain what is meant by main idea, how the main idea might differ from the topic, and why the main idea is so important. Next, students can be asked if they ever have difficulty finding the main idea. If so, what clues did they use? The students' attention is focused on the labeled footprints on the poster.



3. Guided Practice

   The strategy is now applied to a specific passage from the students' textbook. The students are asked to use information from their textbook to complete a footprint hand-out (reduced copy of a poster) directed at finding the main idea.

4. Specific Feedback and Consolidation

   The teacher models the process by thinking-aloud as each footprint is considered.

5. Independent Practice and Transfer of Ownership

   The teacher requires students to use this strategy on each of the next four to six science reading assignments.

6. Application

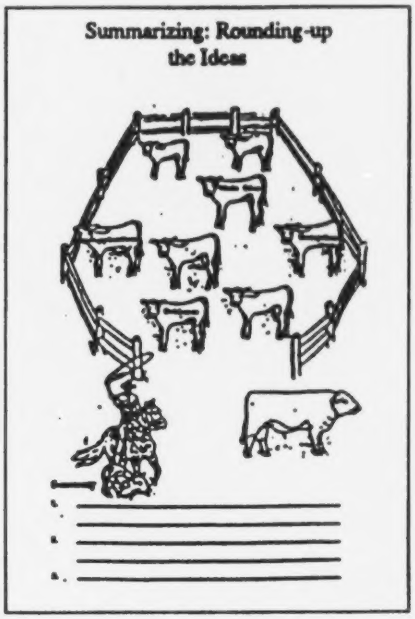
   The teacher reminds, encourages, and reinforces the use of this strategy when appropriate. Encouragement is given to students using the strategy.

Figure 2

Explicit Instruction about Summarizing—Rounding-up Ideas

1. Understanding the Metaphor
   The teacher, dressed in western hat, jeans, shirt and boots, carrying a lasso, introduces the poster illustrating a round-up of cattle into a corral. A clear differentiation of cows and calves is provided. Calves in the corral are labeled (main idea, evidence, exceptions, applications) while the others are not.

2. Direct Explanation
   Discussion of the poster compares a round-up with a summary. Direct questions reveal the fact that calves are rounded-up while yearlings and cows are not. Attention is directed to the labeled calves, and additional labels are added to unlabelled calves in the corral. A rationale for each type of idea to be included in the summary is developed and added to the poster.



3. Guided Practice
   The strategy is applied to a specific passage from the students' textbook. The students are asked to read the text and complete a round-up hand-out on summarizing.

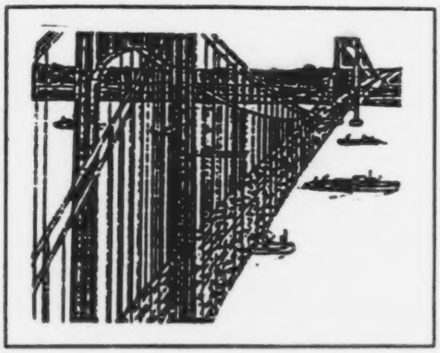
4. Specific Feedback and Consolidation
   The teacher discusses the type of information and the synthesis process used in composing the summary. A think-aloud approach is used to make the thinking process evident to students.

5. Independent Practice and Transfer of Ownership
   The teacher requires the students to complete a summary hand-out for the next four to six reading assignments. The actual summaries are entered in the learning journals as a three-sentence summary. The first sentence identifies the main idea. The second sentence provide supportive detail or evidence. The third sentence provide a relevant application of the main idea.

6. Application
   Cooperative review groups are established to identify main ideas, evidence, and applications of each lesson. These ideas are summarized in the students' journals.

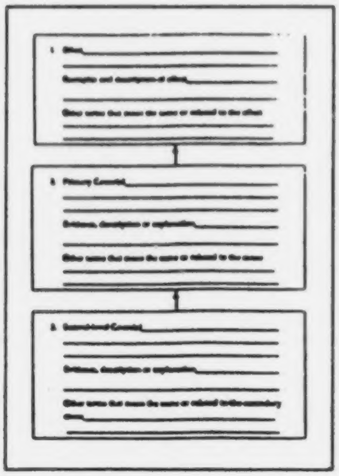
Figure 3
Explicit Instruction about Cause/Effect Text Structure

1. Understanding the Metaphor
The teacher, dressed in jeans, work shirt, boots and hard hat, carrying a roll of blueprints, addresses the poster of a bridge entitled function and structure. The students are asked to identify examples of the function-structure relationship in the natural environment and the people-built environment. The discussion explores how the construction worker uses function-structure relationships. The teacher then directs their attention to the function-structure of written materials —stories, news articles, etc.



2. Direct Explanation
The teacher introduces the use of function-structure relationship in scientific writing. The scientific journal format —purpose, problem, hypothesis, material, procedure, data, analysis, and conclusion — is discussed. The teacher points out that this standard reporting format does not accurately reflect how scientists solve problems but it does provide a consistent format for journal readers. The teacher introduces the five common functions and structures used in scientific writing:
   a. Reporting observations and measurements—**description.**
   b. Reporting characteristics—**collection.**
   c. Reporting likes/dislikes of two or more ideas—**compare/contrast.**
   d. Reporting cause-effect relationships—**causation.**
   e. Reporting problem-solving—**problem-solution.**

   Overhead transparencies of the templates for each text structure are projected and discussed. The benefits of using these graphic displays for organizing information are discussed.



3. Guided Practice
The cause/effect frame is applied to specific text from the students' textbook. The students are asked to read the passage and complete the template.

4. Specific Feedback and Consolidation
The teacher discusses the completed template and where information was found. The general characteristics of cause/effect text are described: two or more paragraphs sequenced to describe the effect and factors related to the result in a causal relationship. The teacher uses a think-aloud approach to clarify the process for students.

5. Independent Practice and Transfer of Ownership
The cause/effect template is used when text passages are encountered in the science textbook until students are sufficiently confident without it. The cause/effect template is also used as a basis for writing cause/effect passages from data collected during experiments.

6. Application
This text structure and template are used in writing and reading in social studies and in science articles or science tradebooks.

structures: description, collection, compare/contrast, causation, and problem-solution. Each structure has its own predictable logic and organization. Unfortunately these text structures differ slightly from the writing genre discussed in writing to learn. Effective readers are able to identify these text structures and to use the knowledge of these structures to improve comprehension. Armbruster (1991) reported that instruction on these text structures improves reading comprehension. Armbruster, Anderson, and Ostertag (1989) described how to use specific templates to assist readers develop proficiency with various text structures and improve comprehension. The following example applies this approach to a cause/effect textual passage (Figure 3).

Explicit Science Writing Instruction

A problem faced by teachers in writing-to-learn science activities is students copying undigested chunks of material that are not understood nor, consequently, remembered. The reason that students copy from their resource books is threefold: (1) the resource material is already in required form; (2) students are reading text written by experts and writing to an informed audience; and (3) the writing is not focused on authentic questions requiring synthesis of ideas into unifying concepts (Anthony, Johnson & Yore, 1996).

Writing a science 'report' usually means an informative, factual expository report. The research information for the science report is normally obtained from one or more resources, most frequently books. The resource books consulted by the students are already framed as informative, factual expositions and a single source contains far more information on the topic than needed or expected. Thus students are faced with a transportation and edit-to-length problem rather and a transformation, interpretative, and synthesis problem.

The problem is compounded by the fact that both the author of the text and the audience (the teacher) knows more about the topic than the student writers. Thus, students read and write beyond their level of expertise. Novice writers are called upon (a) to read in an area about which they have little concrete experience and know little, (b) to develop expertise, and (c) to write in a form that is used to "inform" someone who may well know more about the topic.

Report writing assignments are frequently topic centered and fact focussed. The teacher decides on a broad topic to be addressed, identifies a number of components within the topic, and assigns one component to each student or small group. The teacher may well take the students through a K-W-L sequence but the questions generated are frequently factual rather than strategic. Such low-level questions may be answered with specifics (knowledge telling), therefore the students arrive at the resource material lacking a strategic question that requires them to analyze, synthesize or verify the isolated text-explicit information (knowledge transforming).

One simple way to discourage copying is to separate resources and notebooks and to utilize a variety of resources—concrete experiments, videos, internet, books, pictures, experts, etc. Designating an area of the classroom as the resource centre where a variety of resources are displayed and another area for writing limits the copying problem (Anthony, Johnson & Yore, 1996). The separation rule says: *At your desk you may have either a resource book or your notebook but you may not have both.* There is no limit on the times resources and notebooks may be exchanged. This system has been used successfully with very young students. One of the first strategies employed by students is "remember one word at a time," but leg fatigue requires them to move on to the "read and understand the ideas" strategy.

The "beyond the level of expertise" problem can be partially solved by having the novices collaboratively research different sources and write to inform their peers. Collaboration in the early information selecting and processing stages encourages novices to share ideas and negotiate meaning with others of equal backgrounds. This procedure becomes exciting when the group encounters discrepant information from different sources that requires them to determine the most valid information or representation. Collaboration helps the group build expertise together. A sharing session in which each group presents their material to the rest of the class provides an authentic audience. An alternative maneuver is to have older children write for younger children. Buddy systems, frequently used to enhance reading, can be modified to provide an authentic audience for young science writers.

The "lack of strategic focus" problem can be solved by the use of radiant questions (Anthony, Johnson & Yore, 1996). A radiant question is one that elicits different but connected answers depending on where one looks for an answer. The adoption of a radiant question makes an enormous psychological difference when the students arrive at their resource books. Resources will present ample material that pertains to their question, but no single resource addresses the total question. The novices must read and write selectively. The radiant question requires the students to be selective, inferential, and critical to find appropriate information and to address discrepant information. Such text-implicit questions require the students to infer, access other information, compare-contrast, analyze, and generalize—the fundamental cognitive processes of science.

The Information Retrieval Matrix

Writing an informational report is neither a miraculous nor mysterious task. Rather it is simply a matter of making explicit those features of thought and language that are the instructional goals of the assigned task. This example describes the process of instructing a class in the task of writing an informational report about population traits and genetics. The explicit instruction procedure is focused on writing to learn by establishing an information retrieval matrix to support the interpretation of information, explicitly modeling the conventions of writing in science, guided practice of the approach, and independent application of the procedure to generate a descriptive, instructive, explanative, or argumentative report.

A writing-to -learn science experience designed to introduce different genre can be illustrated by using an information retrieval matrix (columns for questions and rows for information sources) to establish strategic questions and collect information about population variation in traits, reproduction, heredity, chromosomes, genes, dominant traits, recessive traits, and patterns of inheritance. A K-W-L chart is used to organize the knowledge and questions about large posters illustrating life cycles and new generations of people, cats, dogs, and roses. Questions naturally arise as the variation in observable traits increase within a group or whether the grouping represents a "biological family," what causes the variation, and why some groupings have very small variations. These types of questions will provide the central foundation for the radiant questions used to set the writing assignments.

After the "K" and "W" are completed, the first concrete inquiry should involve collecting data about the students' observable traits (eye color, hair color, handedness, tongue rolling, widow's peak, detached earlobes, relative length of the pointer and ring fingers, etc.). These data can be graphed for the class to determine most common traits and population variations. The graph can be used to write and illustrate descriptions of the most common or least common student in the class. A "child find" poster could be used as a model for writing a description.

Next, the individual students' traits can be color-coded onto a paper strip divided into a specific number of rows equal to the traits observed representing the genes in a chromosome. The paper strip can be cut longitudinally. One-half of the chromosome can be traded with someone. Additional trades can be made, but half of the student's original chromosomes must be retained. The two halves of the paper chromosomes are taped together to represent the gene pairs of a complete chromosome. The resulting chromosome is then interpreted. Matched pairs of genes clearly result in predictable traits, but unmatched pairs of genes require further exploration. Appropriate text, video, internet, and experts should be consulted to establish dominant and recessive traits and patterns of inheritance.

After the exploration students are randomly assigned a number 1, 2, 3, or 4. The assigned numbers correspond to a specific writing task.

1. Describe your offspring represented by the paper chromosome.
2. Tell someone how to determine the traits of the offspring represented by the
3. Explain why unmatched pairs of genes on the paper chromosome could increase variation in the next generation.
4. Argue why eye, hair and skin colors of the world's population will likely get darker as people mix.

Small groups can be formed out of students assigned the same radiant question (1's, 2's, 3's or 4's). The groups form "expert" groups like a "jig-saw" approach to research, discuss, and write.

Collaboration is encouraged, but individual written assignments are expected. The completed writing tasks are shared with peers from the other expert groups and with peers from the other radiant question groups. Whole group discussion should consolidate the scientific understanding and clarify the structural characteristics of each written form used to describe, instruct, explain, and argue.

Promising Applications

Simply increasing the number of hands-on activities in science is not the solution to the science literacy issue. We must selectively infuse other tasks into our science instruction that ensures students' minds are on during these hands-on experiences and that promotes the strategies required of life-long learners. Tasks that have significant and discernibly positive effects are reading-to-learn strategies (Holden, 1996; Spence, 1994) and writing-to-learn science using appropriate genre (Fellow, 1994; Key, 1994; Rivard, 1996). These tasks encourage students to engage prior knowledge structures, access print-base information systems, construct new ideas, reorganize knowledge structures, integrate new and old knowledge, seek real world applications, and persuade others to take action. We believe that reading-to-learn strategies and writing-to-learn strategies have the benefits of improved conceptual understanding and memory and the benefit of improved communication of these informed perspectives—science literacy.

If conceptual change and comprehension are prime objectives of science instruction and if scientific literacy involves a dimension of intellectual liberation, active citizenship, and life–long learning, then explicit instruction in science reading and writing strategies must be a part of the overall science program. Hynd, Qian, Ridgeway and Pickle (1991) pointed out that both hands-on inquiry and print-based information require supportive scaffolding to ensure conceptual change. Strategic science reading and writing instruction must keep improved science literacy as its central focus and it should engage prior conceptions, resolve contradictions, facilitate restructuring of understanding, and illustrate real-life applications. Furthermore, strategies instruction should provide students with metacognitive knowledge about using these strategies (WHAT are they? HOW are they used? WHEN should they be used? WHY use them?) as well as executive control dealing with strategic planning, selection, self-monitoring, and regulating effort.

We have found that reading and writing strategy instruction are inter-related, are cross-disciplinary, and are receiving greater attention in the professional journals. The examples included in this paper clearly illustrate the potential of writing to read and reading to write. Analysis of social studies textual materials and mathematical textual materials demonstrates significant similarities among science, social studies, and mathematics text and dissimilarities between any of these and narrative text. The annotated bibliography of recent articles from science education and language education journals illustrates the type of science reading and science writing ideas being promoted (Appendix A). Inclusion of the entries into the annotated bibliography does not indicate unreserved endorsement of each idea since many of these professional articles do not provide adequate research evidence and clear theoretical warrants for their claims. These articles are reasonable resources to use with pre-service and inservice elementary teachers.

The genre that have specific applications in science (description, explanation, instruction, argumentation) are flexible, and the writer must control the specific form to address the function or purpose. If you use templates to introduce these genre, you must explicitly develop the idea that variation in form to address function is appropriate. Armbruster, Anderson, and Ostertag (1989) provide four templates for problem-solution, compare-contrast, sequence, and cause-effect that could be slightly modified to match the genre theory and be used to improve reading comprehension and expository writing.

No lengthy piece of text uses a single genre. Analysis of effective writing illustrates micro-structures embedded within the macro-structure. In argumentation a writer might start with a descriptive passage to engage the reader, later the writer uses an explanation passage to illustrate a critical cause-effect relationship, and in closing the writer may use an instruction passage much the way a judge clarifies the issues, critical evidence, and the charge.

Reflections on recent research indicate that greatest effects of reading and writing to learn occur when the strategies are implemented across the curriculum and not restricted to a single discipline. Spence (1994) found numerous opportunities to apply the expository reading strategies discussed in this paper in social studies, mathematics, and language arts. We believe that a similar impact will be found for science writing strategies as the research foundation increases. Integration of science and language arts have proven time-efficiencies and improves both science and reading achievement and attitudes (Romance & Vitale, 1992).

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Appendix A
Annotated Bibliography

Articles on Reading in Science

Breger, D.C. (1995). The inquiry paper. Science Scope. 18 (11). 27-32.

Breger discusses using inquiry papers, short weekly papers based on independent readings, to help students understand what they have read. In writing these papers, students learn to organize and respond to scientific text as well as learning skills that promote life-long learning. Breger explains that modeling the process for the students is necessary, creating first a reading log, leading to an inquiry paper. A scoring rubric is provided for the assessment of the inquiry papers. As well, a list of sources on which students can base their papers is included.

Casteel, C.P., & Isom, B.A. (1994). Reciprocal processes in science and literacy learning. The Reading Teacher. 47 (7). 538-544.

Casteel and Isom examine the parallel processes at work between literacy and science. They maintain that many of the process skills inherent in literacy are also an integral part of science and that these similarities can be used to help students in their learning. The authors also point out the value of using literature in the science program to make the unfamiliar more familiar. As well, Casteel and Isom advocate having students write and reflect about their experiences in science in order to foster further learning and understanding.

Center for Applied Linguistics. (1993). Integrating math and science with language instruction. Washington, DC: Author.

This document describes a program established by the Center for Applied Linguistics to improve math and science education for language minority students. To do this, two in-service training sessions were initiated for a number of classroom teachers. The goals of the in-services were to introduce teachers to the communicative approach to math and science, to develop instructional materials which aid in the integration of these subjects, to develop appropriate instructional and assessment practices, and to train teachers to train others in these methods. According to this report, the program was successful in attaining these goals.

Charron, E. & De Onis, A. (1993). More complementary than contrary. Science Activities. 30 (1). 13-17.

Charron and De Onis suggested that the gap between teachers who teach a "read the chapter and answer the questions" science lesson, and those who provide hands-on experiences is narrowing. A re-examination of the role of reading in science, and the need to include real-life experiences are two reasons for this changing view. Teachers are realizing that children need to create their own ideas about new concepts through self-exploration. An integrated teaching approach has also given teachers more time to facilitate this type of learning. Charron and De Onis believed that reading cannot take the place of doing science, but that the use of multiple information sources enhances learning. Charron and De Onis discussed how two teachers combine their interests to develop collaboratively a four step program that includes brainstorming sessions, activities, and reading. Both teachers believed that science should be taught using an equal combination of reading and doing and not used in isolation.

Drake, S.M., Hemphill, B. & Chappel, R. (1996) A novel approach. The Science Teacher. 63 (7), 36-39.

This article describes how a grade nine class connected the novel Ring Rise, Ring Set to science. The novel had a heavy science content which the teacher used to pique students curiosity. The question asked was: were the scientific concepts encountered in the novel just science fiction or sound scientific thinking? This central issue served as a springboard for inquiry. The students went through several different scientific experiments to explore science and science-like ideas. The authors claim that the scientific content resembled a traditional ninth-grade program but in this approach the content was set in a more relevant context and therefore sparked the students' curiosity.

Eggerton, S. (1996). Balancing science and sentiment: The portrayal of nature and the environment in children's literature. Science and Children. 33 (6). 20-23.

Eggerton examines the on-going controversy of scientific accuracy versus sentiment in children's literature. There are those who argue that imagination and real world overlapping create for children curiosity and interest. However, others argue that this overlap leads to the development of misconceptions in children's thinking. Eggerton explains that critical assessments must be made when choosing books on nature and the environment. Furthermore, it is essential that real life connections are made when using literature.

Farris, P.J. & Fuhler, C.J. (1994). Developing social studies concepts through picture books. The Reading Teacher. 47 (5). 380-387.

In their article, Farris and Fuhler advocate the use of picture books in the classroom to teach concepts to students. They explain that picture books add detailed information which is lacking in many traditional textbooks. Picture books also lend themselves to the exploration of sensitive or controversial issues. Furthermore, picture books provoke curiosity and questions from students. Picture books can be used to make the abstract more real to students. The authors provide more in depth analysis of how picture books can be used in each of the following areas: anthropology, geography, history, and sociology.

Huber, R.A.& Walker, B.L. (1996). Science reading dos and don'ts. Science Scope. 20 (1), 22-23.

Huber and Waker suggest that students must read about science in order to gain more information in addition to doing science. They explain that this provides the opportunity to teach students about science as well as improve their science reading skills. They provide a list of suggestions that can help science teachers support their students' growth in science knowledge and as readers. The list consists of the dos and don'ts involved when teaching science reading skills that promote a positive self-concept, attitude toward science reading and strategic approach to science reading.

Mayer, D.A. (1995). How can we best use children's literature in teaching science concepts? Science and Children. 32 (6). 16-19.

Mayer examines the use of children's literature in science programs. Using a variety of literature which is used in teaching science, the author set out to determine what students learn from the use of fiction (a checklist was developed to determine the suitability of the book). In the study, Mayer discovered that fiction may interfere with the acquisition of knowledge. It was further expressed that when choosing literature in the classroom, care should be taken to ensure accuracy of information in both the text and the illustrations to reduce possible misconception which may ensue.

Olson, M.W. & Gee, T.C. (1991). Content reading instruction in the primary grades: Perceptions and strategies. The Reading Teacher. 45 (4). 298-307.

This article examines the need for young children to develop proficiency with expository texts, even in the primary grades. Having completed a survey, Olson and Gee share commonly recommended practices of primary teachers for content reading and also suggest specific strategies which are accompanied with examples to illustrate them. These strategies include: semantic mapping, KWL (what I know, what I want to learn, what I have learned), concrete manipulatives, expository paragraph frames, group summarizing, and visual imagery.

Schumm, J.S., Vaughn, S., & Leavell, A.G. (1994). Planning pyramid: A framework for planning for diverse student needs during content area instruction. The Reading Teacher. 47 (8). 608-615.

The authors explain a framework for planning content area: a planning pyramid. The pyramid allows for inclusionary instruction for children with a broad range of abilities. The three degrees of learning examined are: what all student should know, what most but not all students will learn, and what some students will learn. The five points of entry described are: student, teacher, instructional practices, topic, and context. An example, using simple machines, is provided to illustrate the planning pyramid.

Current Articles on Writing in Science

Clidas, J. (1996). Personal plot journals. Science and Children. 33 (6), 22-25.

In this article Clidas describes how she organized and implemented 3m by 3m environmental study areas for her fourth-grade class. She goes on to describe the journals her students kept while visiting their plots twice monthly. These journals supported her students' science inquiry and learning and documented change over time. The field journals encourage her students to write like scientists, which in turn encourage them to observe, and think like scientists.

Ediger, M. (1994/1995). Writing in the science curriculum. Catalyst. 38 (2). 36-41.

Ediger strongly advocates the use of writing in the science curriculum. He explains that clear communication of thoughts and ideas is imperative. As well, he demonstrates that writing does, in fact, aid students in learning and reflecting. Ediger recommends writing be used in the following forms: experience charts, outlining content, experiments, book reports, journals, diaries, and logs in order to provide optimal learning and understanding for students.

Johnson, T, Hawe, M. & Burkimar, J. (1995/1996). Augmentation: Extending ideas in report writing. Prime Areas. 38 (3), 41-45.

Johnson, Hawe and Burkimar advocate the augmentation of a core text as a way for students to write reports. To augment a core text the students take a normal text and surround it with factual and fictional information. The original text is referred to as the core text. The additions represent the augmentation. They claim that by using augmentation, instead of copying, there is a significant increase in the quality of children's engagement and understanding of the source materials, and their written reports. These important cognitive activities happen because augmentation requires transformation of information and ideas encountered in the text. Augmentation also gives the students experience in writing expository texts. Johnson and Hawe give clear example of students' augmented reports, and how they are done in a classroom setting.

Ogens, E.M. (1996). The write stuff. Science Scope. 20 (1), 15-17.

Ogens examines the use of journal writing in science class in this article. She describes how she uses journals in her classroom which include: to close a unit through summary of ideas learned, setting goals, recording progress, and posing further questions. She also uses journal writing to determine the level of understanding of the concepts taught and to help her identify the areas that need more clarification. As well, Ogens advocates journals as an invaluable instrument for promoting student-teacher dialogue -- conduit for learning.

Reif, R.J. & Rauch, K. (1994). Science in their own words. Science and Children. 31 (4). 31-33.

Reif and Rauch outline the value of students creating their own science books. This activity allows students to design, to write, and to illustrate their own books, making science learning relevant to them. Students are able to share their books with their class and with other students in the school. It is also explained that this project is ideal as it can be adapted to the level at which the children are working. The authors suggest three formats the books may take: alphabet book, concept book, or science narrative. The further offer a variety of suggestions for illustration.

Rillero, P., Zambo, R., Cleland, J., & Ryan, J. (1996). Write from the start: Writing to learn science. Science Scope. 19 (7). 30-32.

In this article, the authors advocate using the first few minutes of class for an activity called "Write Now." Students are asked to respond to a "quasar question"--powerful, open-ended questions which foster reflection and understanding. The teacher can use the questions as a form of daily assessment as well, assessing conceptual knowledge and misconceptions. The class can share responses and a discussion may develop from the varying viewpoints. The authors have provided examples of quasar questions and a variety of classroom strategies for using them.

Ryan, J., Rillero, P., Cleland, J., & Zambo, R. (1996). Writing to learn math and science. Teaching K-8. 27 (1), 78-81.

The "Write Now" approach is a writing to learn math and science program [also see Science Scope, 19 (7)]. This is a warm-up approach which includes using an open-ended question posted in the front of the room upon the students arrival. The students answer the question by elaborating on what they learned in the previous days' lesson. This approach provides the teacher with a chance to see whether the students have understood the lesson from the previous day and to assess other prior knowledge related to the topic. The article further explains the types of science and math questions that work for this approach, and they claim that open-ended questions work the best.

Scarnati, J.T. & Weller, C.J. (1992). Write stuff. Science and Children. 30 (4). 28-29.

Scarnati and Weller advocate the integration of language arts into science. The authors suggest that narration, description, explanation, and persuasion are the four basic methods of writing. These should be a student's "main purpose in writing" rather than watching for errors, such as "misspellings, grammatical errors, and messy penmanship." Scarnati and Weller believed that there is "no better subject in which to practice these skills than science." By reporting on science activities, and keeping observations, students are in a situation where a need for different writing form exists. "Integrating science and language arts is easy to do as long as you keep in mind the four purposes for writing and recognize the relationship between writing and science inquiry skills."

Articles on Integrated Reading and Writing in Science

Jaegar, M., Lauritzen, C. & Davenport, M.R. (1996). Integrating curriculum. The Reading Teacher. 50 (1), 64-66.

The authors describe an integrated approach to the study of Hot Lake: a local hot springs site with old buildings and ponds. This mysterious environment with steamy waters, ghosts haunting the legendary spa provide a high motivation and interesting focus for experimentation. The students pursued the discipline of science, acted as engineers, and explored folklore and history in this study. The authors also explain the idea that teachers and students who have an understanding of the nature of these disciplines can further use this understanding as a prism for examining contexts, generating inquires, and determining explorations. The oral and print language arts are essential in the construction of understanding and in the sharing of ideas.

Lozauskas, D. & Barell, J. (1992). Reflective reading. The Science Teacher. 59 (8). 42-45.

Lozauskas and Barell encourage the use of a "thinking journal" in the science classroom wherein students write their thoughts while they read science materials or perform science experiments. It is important for the teacher to model how to write in these journals using a "think aloud" technique. The authors give a list of "starters" for the journal entries. They further explain the usefulness of journals in the insight they can give regarding the students thought processes and as a means of communicating through a running dialogue.

O'Mallan, R.P., Foley, C.L., & Lewis, C.D. (1993). Effects of the guided reading procedure on fifth graders' summary writing and comprehension of science text. Reading Improvement. 30 (4). 194-201.

The authors of this article examine the use of the Guided Reading Procedure (GRP) in writing summaries. Two groups of students participated: the control group was given a traditional science program while the experimental group practiced GRP through a process of gradual release. Through examination of products, including a pre and post test, it was determined that students may initially struggle with comprehension when first learning the GRP strategy; however, it is speculated that this lessens with familiarity. Summary writing improved--evaluators saw increased paraphrasing and decreased reproductions in the students' writing.

Schroder, G. (1996) The elements of story writing: using picturebooks to learn about the elements of chemistry. Language Arts. 73. 412-418.

In this article Schroder writes about how her grade six class wrote and illustrated picturebooks for younger children to help make abstract and difficult science concepts more understandable. Schroder talks about each step of her project which includes taking students through: research, modelling, developing a plan of action, drafting, final revision and editing, and sharing the finished product: publishing. Schroder claims picturebooks were the natural bridge that made the study of elements meaningful to sixth grade students.

VIEWS ABOUT AND ACTIONS TAKEN ON GLOBAL ATMOSPHERIC CHANGE ISSUES BY MIDDLE AND HIGH SCHOOL TEACHERS OF SCIENCE PARTICIPATING IN AN STS TEACHER ENHANCEMENT INSTITUTE[1]

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Role-models have long been significant in helping to advance the ideals of society and good citizenship. Modeling (i.e., setting the example) continues to be commonly acknowledged as an effective teaching strategy for citizenship behaviors. Not only are teachers commonly held up as role models of appropriate citizenship (E. Holland, 1994; S. Holland, 1991), and in addition serve as role-models for would-be teachers (Stiegelbauer, 1992), but also K-12 teachers frequently use modeling in teaching (Baker, 1994, McAloon, 1993; Norman, 1992; Pestel, 1993; Schluter, 1995).

The value of modeling as a teaching strategy notwithstanding, there have been but two published studies on modeling as a science instructional strategy in the past six years. In one, Norman (1992) compared the use of modeling and the learning cycle in teaching science process skills to sixth through ninth grade students. In the other, Pestel (1994) examined the effectiveness of "teaching aloud problem solving" as opposed to modeling in college chemistry. Otherwise, modeling is absent from the recent science education literature. This is especially surprising given the rise in science education of STS (Yager, 1993) with its emphasis on citizenship action as the means toward the resolution of science- and technology-related societal issues (STS issues) (Rubba and Wiesenmayer, 1985, 1988).

Passe (1991) proposed that elementary teachers have great influence as role-models in the area of citizenship education, and so must not only talk-the-talk, but walk-the-walk:

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> Teachers are the most effective models for citizenship education....For this reason, teachers must practice what they preach in the classroom. If teachers show active interest and involvement in citizenship matters,...students will likely do the same. (p.17)

Purpose and Context

In this paper, we examine the views held by four upper elementary teachers involved in STS instruction, through participation in a Leadership Institute in STS Education, on teachers serving as models of responsible citizenship action. The Leadership Institute in STS Education was a four-year collaborative teacher enhancement project of Penn State University and West Virginia University with upper elementary/middle/junior high school science teachers in the areas surrounding these two institutions, which are vastly rural. The major goals of the Institute was to develop teacher-leaders at the middle education levels in STS education. The Institute was funded by a Teacher Enhancement Grant from the National Science Foundation.

Through the Leadership Institute, two dozen upper elementary/middle/junior high school science teachers from rural central Pennsylvania and northern West Virginia participated in professional development activities designed to develop teacher-leaders in the area of STS education. Activities were based on a STS research foundation connected to the long acknowledged scientific literacy goal of K-12 science education. The development and implementation of a STS issue investigation and action curriculum (Rubba & Wiesenmayer, 1988, 1991, 1993) on global warming (hereafter referred to as the STS Unit) served as a focal point for the teacher development activities.

The STS Unit went through multiple editions, each field tested by Institute participants and revised using field test data. Later editions produced during years three and four were expanded to deal with three related STS issues that fall under the global atmospheric change umbrella: enhanced greenhouse effect or global warming, as well as ozone depletion and ozone pollution.

Concurrent with their work in developing the STS Unit, the teachers were involved in science content up-dates (e.g., the science, technology and societal aspects of global atmospheric change), pedagogical renewal (e.g., authentic assessment, cooperative learning, conceptual change teaching), use of the INTERNET for Institute and other communications, conducting inservice workshops on STS education, mentoring other teachers as they implemented the STS Unit, presentations at state and national professional conferences, and co-authoring articles emanating from the Institute (Ditty, Jarosick, Milam, Rubba, Rye, Wiesenmayer, & Yorks, 1993; McLaren, Yorks, Yukish, Ditty, Rubba, & Wiesenmayer, 1994). Details on the Institute are available elsewhere (Rubba, Wiesenmayer, Rye & Ditty, 1996). The effectiveness of the teacher-developed STS curricula in changing students' conceptions on global atmospheric change issues and the teachers' experiences in using STS curriculum development as a vehicle for teacher enhancement and improving practice in middle level school science were examined over the course of the Institute (Dorough, Rubba & Rye, 1995; Morphew, 1994; Rye, 1995; Rye, Rubba, & Wiesenmayer, 1994, in press).

Along with the Institute activities noted above, the participants submitting electronic responsive journals on a regular basis and participated in annual interviews. The journal questions focused on science teaching and the integration of STS into science instruction. The interviews mainly focused on issues around implementation of the STS Unit, but also dealt with science teaching and the integration of STS into science instruction within that context.

The desirability of teachers serving as models of citizenship action on a STS issue was not explicitly dealt with in the Institute. However, the STS goal structure that served as an organizer for the Institute and the STS Unit, emphasizes that every citizen has the right, if not the obligation, to help resolve STS issues (Rubba & Wiesenmayer, 1988, 1993). Accordingly, all editions of the STS Unit developed by the teachers had a capstone set of lessons on the development of citizenship actions skills in which students actually took action on global warming. The final edition of the STS Unit, which is entitled *Global atmospheric change: Enhanced greenhouse effect, ozone layer depletion and ground level ozone pollution* (Rubba, Wiesenmayer, Rye, McLaren, Sillman, Yorks, Yukish, Ditty, Morphew, Bradford, Dorough, & Borza, 1995), includes these action lessons as well as accounts of actions actually taken by students of the Institute participants in an appendix. (For a copy of this unit, please see URL http://www.ed.psu.edu/dept/ci/sts/gac-main.html.)

Procedures

Subjects

The subjects for this report included four upper elementary teachers (fifth and sixth grades) from central Pennsylvania who fully participated in the Institute over the first two years while the STS unit primarily focused on global warming. These four teachers are referred to herein as Edie, Jan, Helen, and Chuck.

Edie had been an elementary teacher for 12 years upon joining the Institute. She held a bachelors and master's degree in elementary education, and had completed additional graduate credits in education, including a summer workshop on teaching science by inquiry. Over the period of the Institute Edie was teaching in a partially departmentalized sixth grade wherein she had responsibility for teaching science to three sixth grade sections.

Jan had been an elementary teacher for 5 years. She held a bachelors degree in elementary education and had been working to complete the 24 credits of graduate coursework required in Pennsylvania in order to be permanently certified. Over the period of the Institute, Jan was teaching in a partially departmentalized sixth grade and so was responsible for the science instruction to three sixth grade class sections.

Helen had been an elementary teacher for 15 years. She held a bachelors and master's degrees in elementary education, plus had completed additional graduate courses in education over the past eight years. While in the Institute, Helen was teaching in a partially departmentalized fifth grade and so was responsible for the science instruction to three fifth grade class sections.

Chuck had been an elementary teacher for 17 years. He had a bachelors and master's degree in elementary education plus additional graduate credits in education, including multiple science education workshops. Over the period of the Institute, Chuck was teaching in a self-contained sixth grade, except that he taught science for both sixth grade sections and the other sixth grade teacher taught the social studies for both. Chuck also served as the substitute principal when the principal was at one of the other two elementary buildings to which he was assigned.

All four teachers indicated an interest in global warming as a timely issue in early journal entries. They each had joined the Institute expecting to develop a greater understanding of global warming and to gain teaching resources on the topic, particularly the STS Unit that was to be developed, but also other resources, such as textual material, videos bulletin boards, and access to university faculty resources in science and education. Being connected to the INTERNET for e-mail was an additional incentive noted by each teacher.

Data Sources and Analysis

Approximately once a month responsive journal questions on science teaching and the integration of STS into science instruction were posed to the participants, during summer periods or residence at Penn State or West Virginia University in writing and during the academic year via e-mail. Responses were submitted directly to the project director. An example responsive journal question set is presented in Figure 1, below.

Please share your views on the following questions:

- To what degree do you believe you are "environmentally responsible?"
- What is it that you do or refrain from doing that is "environmentally responsible?"
- As you reflect upon the way you live, are there other things that you are willing to do or refrain from doing that would make you more environmentally responsible?"
- To what degree, if any, do you believe that science teachers should be "environmentally responsible." Please explain your response.

Figure 1. An Example Responsive Journal Question Set.

At two points during the first and second academic years of the Institute, about two weeks after the STS Unit was implemented and typically during the second semester, staff members visited each participant's school to interview the participant (as well as six to eight students). Standardized open-ended interview protocols (Patton, 1987) were used in conducting the teacher interviews. All teacher interviews were conducted in a private room (typically an office) and took approximately 35 minutes. These interviews were tape recorded, transcribed, and the transcripts verified and corrected as needed. An example excerpt from a teachers interview protocol is presented in Figure 2, below.

- Do you consider global warming a threat?
  What makes you say that?
- Is this the position on global warming you held when you started the Institute?
  Please explain. *(If no change is noted, go to the next item)*
  What caused the change?
- What would it take to now convince you that global warming is/is not (the opposite view) a threat?
  Why do you say that?
- Have you taken any actions in support of your position on global warming?
  Tell me about your decision to take/not take action.
- Do science teachers have any special responsibilities where taking action on STS issues is concerned?
  Please explain.

Figure 2. An Example Teacher Interview Excerpt.

The journal questions posed in year one were repeated in year two. Also, the interview protocols were similar both years. These procedures were approved by the institutional review boards for the protection of human subjects involved in research at each university.

Understanding the degree to which the four teachers considered global warming a threat and the degree to which they took actions in support of their position on global warming, were considered requisite to understanding their views on teachers serving as models of responsible citizenship action. Relevant journal entries and interview responses from both years were reviewed to identify emergent patterns relative to these three areas.

Findings and Discussion

To what degree did the teachers consider global warming a threat?

In a second year journal entry and interview, the teachers were specifically asked to rate global warming as a threat and provide justification for the rating. In both the journal entry and interview, all four teachers rated global warming as a serious threat -- 8 or above on a 10 point scale -- and added supporting justifications based upon the continuing worldwide production of greenhouse gases, i.e., carbon dioxide, CFCs, methane, water vapor. For example:

> Helen: 10 -- The greenhouse gases that our lifestyle has put into the atmosphere greatly increase the greenhouse effect.

> Chuck: 8 -- Carbon dioxide is going to have a direct negative result on temperature, which will change climate patterns and result in possible agricultural problems....
>
> The development of the Third World Countries scares me the most....I think the rest of the world is going to want to catch up with our technology. China scares me more than anything....[U]nless we do something about the Third World,...how we move them into the twenty-first century, I don't think we have a chance.

In response to the first year interview question, "Was this the position you held when you started the Institute?" Helen indicated that she had considered global warming a threat 10 months earlier -- prior to joining the Institute:

> Helen: Yes, although I probably didn't think about it much. But yes, I'm sure, yes.

Chuck admitted to initially confusing global warming with ozone depletion -- a commonly held alternative conception is that the latter is a principle cause of the former (Boyes & Stanisstreet, 1993; Dorough, Rubba, & Rye, 1995; Francis, Boyes, Qualter, & Stanisstreet, 1993; Koulaidis & Christidou, 1993; Rye, 1995; Rye, Rubba, & Wiesenmayer, in press).

Chuck: I thought global warming was related to ozone depletion. I was ignorant of that, as most [people] are.

However, prior to beginning the Institute 10 months earlier, none of the teachers listed global warming among the top dozen STS issues they believed faced humankind.

When challenged in the second year interview with the question, "What would it take for me to convince you that global warming is not serious?" each of the teachers indicated being secure with his/her beliefs. For example:

Jan: I don't think you could do that. I don't think you could honestly do that.

Chuck: I don't think you could do that. I mean, the facts are out there.

To what degree did the teachers take actions in support of their positions on global warming?

Both in early first year journal entries and similar second year ones, all four teachers indicated that they were "trying to" be environmentally responsible. In support they noted example personal actions, but also admitted to some irresponsible actions.

Edie: I would like to be more environmentally responsible and share my ideas with my students whenever it lends itself to whatever we're doing in class. My family recycles glass, plastic and aluminum (we drive 8 miles to a recycling center each month). We compost...and do not use pesticides and herbicides....I believe that I am much more "environmentally responsible" now than I was five years ago. I also teach environmentally good practices to my family, friends, and students every chance I get!!!

Our goal for 1992-93 is to build a more earth friendly home on land we have just purchased bordering an 11,000 acre conservancy. I also plan to TRY

AGAIN to interest our principal in a recycling program at school, along with taking action against a local polluter (next door to our school!).

Helen: I try. I think that almost daily I consciously keep environmental concerns in my decision making.

Sometimes I do choose to go ahead with actions that I know are not the correct choice environmentally, either because it is cheaper or more convenient, but I usually try to choose actions based on environmental concerns....I keep the thermostat set low in the winter. No air conditioning. I carry cloth bags to the grocery store....I used cloth diapers (when kids were little.)....I have personally planted thousands of trees [on our tree farm].

[On the other hand,] my showers are too long, we do not recycle as much as we should...(the centers I took my recyclables to all closed). Also, living in a rural area, I do drive more than I would like....

Jan: It is getting easier for me to be more responsible since our children are leaving home....When he [oldest child] comes home to visit, it's the same old story, however....

I learned that using chlorine bleach isn't environmentally safe, so I'm trying to wean myself of that but I haven't found any product that equals bleach for whitening....

I do enjoy some creature comforts such as hot water, clean clothing (ironed), driving by myself....This list doesn't seem too bad to me.

Chuck: I feel I'm a fairly environmentally responsible person. I try very hard to practice what I preach in school -- recycle, use products that are

> environmentally friendly. I encourage friends, family and my students whenever I can to become more aware of our environmental responsibility....A lot of what I do is consumer oriented that deals with what I buy and [do] not purchase.

Many of the actions noted by the teachers were unique in the sense of being atypical for the time period (the early 1990s) and rural areas. For example, recycling was not mandatory in Pennsylvania at the time, most of the recycling centers were privately owned, and few were located in rural areas. Still, none were linked by the teachers in their journal or interview responses specifically to global warming or to the other related global atmospheric change issues (i.e., ozone depletion in the upper atmosphere, ground level ozone pollution), and the actions they reported taking, for all practical purposes, did not change over the year between interviews and similar journal entries. Additionally, implied within the journal and interview responses of the teachers, was the understanding that many of the actions were ongoing and initiated prior to the beginning of the Institute in response to environmental concerns other than global warming. As noted above, Helen indicated that she had considered global warming a threat prior to joining the Institute.

The following teacher statements from the late interview provide other supporting examples:

> Edie: I would hope that I have always been a bit conscious of my actions....I have always tried to take the shopping bags, turn the water off, not make extra trips. All those things,...I think goes back at least 20 years...to the first Earth Day. I remember being a teacher at the time and taking kids out...to plant some trees....

> Jan: [I have been doing] What I do normally. Maybe I do it a little more. Maybe I'm more conscious of what I do.

And Chuck, in comparing the actions he supposedly took on global warming to his activism on the Vietnam War, noted, "I'm [now] much more outspoken about it [--my actions]."

What were the four teachers' views on teachers serving as models of responsible citizenship action?

In an early journal entry, Edie noted a felt obligation --

> ...to present to my students the environmental issues which are going to effect and change life on this planet (as we know it) in the years to come....It's time (or past time) for all teachers to take a stand and do our part to educate and encourage a commitment from our students to "turn the tide" on the reckless devastation of our world....I feel that it is of utmost importance...."

Chuck expressed similar motives:

> Educating our students and making them aware of what is going on will allow them to make better decisions as they get older....We must expose them to the current issues and problems for they must be included in the process to change present day beliefs and ideas into worthwhile solutions for our environment.

Directly addressing the journal item, "To what degree, if any, do you believe that science teachers should be "environmentally responsible?" early in the Institute, Edie noted:

> We should "practice what we preach" -- or we're being just as hypocritical as those in government who vow to work for change and then forget what they promised to do -- once in office. Our students need role models, not more actors and actresses. We have too many of those already.

One year later, she expressed similar sentiments:

> As a teacher, I have a very unique opportunity to be a role model in all that I do to help the environment. I can share the many things that I believe will contribute to a cleaner, healthier environment with my students. I can also "practice what I preach" right in my classroom (recycling paper, not using any Styrofoam, always using biodegradables...etc.). I feel that's the way all teachers (not just science teachers) lives should be -- representative of how they are being environmentally responsible. It is not a choice; It is an obligation for all of us!!!!

Helen's, Jan's and Chuck's responses to the journal item were similarly consistent across the two years. For example, here are Helen's first and second year entries, respectively, to the same journal item:

> I think the best teaching of values [and] responsibility is done by example. We cannot reasonably tell students to alter behaviors if we will not. Therefore, when I run into a little league team of my students in the grocery store, which I did, they all came up to me to see if I really had my canvas bags. (I did.) Had I not had them, I'm sure discussing behaviors would have been less effective. I really believe we must do those things to set an example.

> By example, we need to make students aware that their actions are important. I always carry cloth bags.... and I often run into my students, who always check...I have a calendar of 365 Ways to Save the Planet. We read those hints daily. I let students know which one of the things I am willing to do with how I live.

When asked in the second year interview whether science teachers have any special personal responsibilities where STS issues are concerned, the teachers responded as follows:

Edie: Absolutely, I don't think any science teacher can avoid presenting the issues that are threatening the planet....[And,] I think that if they teach it, they should live that way.

Helen: Oh absolutely. I think we need to set examples. I think our best teaching is [by] example....[T]hey pick up on those things we do. We can't tell them to do things and not do them ourselves.

Jan: I agree 100% that science teachers have a special responsibility to be good models,...[and] I don't see [it] as my responsibility or part of my classroom in this building alone.

Chuck: I don't know how you could teach science without teaching [it from] an STS approach..., [and] you have to set a good role model.

Summary

The teachers responses to journal and interview questions concerning the degree to which they considered global warming a threat, the degree they took actions in support of their positions on global warming, and their views on teachers serving as models of responsible citizenship action were consistent both across those inquiries and among the four teachers. The teachers considered themselves to be environmentally responsible as a result of environmental actions they were taking. While they connected these actions to the resolution of global warming, the teachers, in fact, initiated the actions before joining the Institute, most likely as part of a general concern about the environment, and prior to recognizing global warming as a highly significant STS issue. The teachers' citizenship action behaviors did not appear to change in concert with the recognition of global warming's significance. One could infer that this relates back to the teachers believing they already were environmentally responsible where global warming was concerned.

The teachers' perspectives on teachers serving as models of responsible citizenship action were strongly consistent with the view expressed by Passe (1991), that elementary teachers have great influence as role-models in the area of citizenship education, and are, in fact, the most effective models for citizenship education. They appeared to operate under the belief that teachers must practice what they preach where responsible citizenship action is concerned, and if teachers show active interest and involvement in taking citizenship action, then students are more likely will do the same.

The views and practices of the four teachers examined in this study on citizenship action notwithstanding, there has been little research on modeling as a science instructional strategy. This would appear to be a fruitful line of inquiry that would have broad implications for science curriculum, instruction and teacher education.

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AN EXPLORATORY STUDY OF THE DISCIPLINARY KNOWLEDGE OF SCIENCE TEACHERS

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Abstract

The purpose of this study was to describe the disciplinary knowledge of a group of science teachers in terms of their knowledge of the structure, function and development of their disciplines, and their understanding of the nature of science. The study also aimed to relate that knowledge to the teachers' level of education, years of teaching experience and the class level(s) that they teach. Twenty inservice science teachers were selected to respond to a modified version of the Views on Science-Technology-Society questionnaire to assess their understanding of the nature of science. The teachers then constructed concept maps and were interviewed. The concept maps were scored and the interviews analyzed to assess teachers' knowledge of the structure, function and development of their disciplines. The teachers' disciplinary knowledge was found to be lacking in all respects. Teachers held several naive views about the nature of science and did not demonstrate adequate knowledge and understanding of the structure, function and development of their disciplines. Moreover, the teachers' disciplinary knowledge did not relate to their years of teaching experience, the class level(s) that they teach and their level of education. It was reasoned that teacher preparation programs are not helping teachers to articulate the disciplinary knowledge needed for teaching science.

Introduction

Science educators and major science education organizations are increasingly advocating the preparation of scientifically literate students (e.g., AAAS, 1989; Lederman, 1992). In very general terms, a scientifically literate person should develop an understanding of the concepts, principles, theories and processes of science, and an awareness of the complex relationships between science, technology and society. More importantly, such a person should develop an understanding of the nature of science.

There may be more than one level of scientific literacy. Anderson (1987) uses the ideas advanced by Bereiter and Scardamalia (1987) to conceptualize two levels of scientific literacy, low and high. Anderson argues that low literacy in science focuses on knowledge of facts about the world, while high literacy centers around the use of scientific facts in the description and explanation of natural phenomena and everyday life experiences. Bereiter and Scardamalia advance that low literacy has historically been characteristic of mass education and prepared citizens qualified for low level, manual jobs while high literacy has been characteristic of the education of the society's elite and qualified them for the more intellectually demanding and creative jobs. However, in light of the increasing automation of manually-based occupations and an increasing demand on highly specialized, brain-intensive occupations, a high level of scientific literacy is becoming a necessity for all students. Bereiter and Scardamalia argue that high levels of literacy may not be achievable by the simplistic solution of modeling mass education after that of the elitist and suggest that an attainable form of high literacy should be made available to all students.

Considering the above, Anderson (1987) defines good science teaching as that geared toward developing an attainable form of high scientific literacy and good science teachers as "those adequately prepared to help their students achieve an attainable form of high literacy" (p. 4). Anderson argues that teachers who are supposed to teach for an attainable form of high scientific literacy, should themselves be highly literate in science. More importantly, those teachers should be capable of transforming their knowledge and understandings of science to a level that students can attain. Without such transformation, teachers' knowledge and understandings would remain virtually tacit and not available for teaching. Teachers would not be able to help students develop the desired understandings of science.

Shulman's Model of Teaching

The centrality of transformation to 'good' teaching was also emphasized by Shulman (1987). Shulman advances that good teaching requires a deep knowledge of the content to be taught interwoven with an adequate model of teaching. Shulman's model of teaching is cyclical. The model has a set of actions which are comprehension, transformation, instruction, evaluation and reflection.

Teaching begins by comprehension. Teachers should comprehend how the ideas within their discipline are inter-related and connected, what is to be taught and how to teach it, and the aims and purposes of teaching. Teachers should also be able to transform their understanding of the subject matter into forms that are attainable by the students and that are simultaneously "pedagogically powerful" (Shulman, 1987, p. 15). After comprehension and transformation comes instruction. Shulman notes that the methods of instruction used in the classroom are directly related to the teacher's content knowledge, and are influenced by his/her personal understanding of the subject matter. Evaluation follows instruction. Such evaluation requires a firm grasp of the subject matter. The final step is reflection on all of the above activities. Shulman suggests that such reflection is not a disposition, nor is it a set of strategies. Content-specific analytical knowledge is needed to reflect on the teaching activities. This process ends by reaching a new comprehension. A new cycle of teaching then commences at a higher level of understanding.

Shulman (1987) also identifies the professional knowledge base needed for 'good' teaching. He enumerates several dimensions of this knowledge base. Among these dimensions are content knowledge, general pedagogical knowledge, and pedagogical content knowledge (PCK). Of particular interest is content knowledge and PCK. Shulman defines content knowledge as knowledge of the substantive and syntactic structures of a discipline. Substantive knowledge refers to knowledge of the global structures or principles of conceptual organization of a discipline. It includes knowledge of facts, concepts, and principles within a content area and knowledge of the relationships between these. Syntactic knowledge, on the other hand, includes knowledge of the "historical and philosophical scholarship on the nature of knowledge" in a discipline (Shulman, 1987, p. 9). It refers to knowledge of the principles of inquiry and values inherent to the field, and of the methods with which new ideas are added and deficient ones are replaced by those who produce knowledge in that field. Applied to the sciences, syntactic knowledge corresponds to an understanding of the nature of science. On the other hand, PCK is presented as "the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented and adapted to the diverse interests and abilities of the learners, and presented for instruction" (Shulman, 1987, p. 8). Under PCK, Shulman includes "the most regularly taught topics in one's subject area" and the alternative and useful ways of representing those topics to make them understandable to students. These alternative representations include "analogies, illustrations, examples, explanations, and demonstrations" (Shulman, 1986, p. 9). Also included under PCK is knowledge of students' misconceptions about the topics most commonly taught and the "instructional conditions necessary to overcome and transform those initial conceptions" (Shulman, 1986, p. 10).

Explication of Shulman's Knowledge Base Specific to the Sciences

Anderson (1987) notes that Shulman (1987) provides answers regarding what prospective teachers need to know (the knowledge base) and how to use that knowledge (the teaching cycle). Anderson acknowledges Shulman's "how" but provides an explication to the "what". This explication, Anderson claims, would have more utility in guiding curricular design for teacher education programs in the sciences.

Anderson (1987) presents a conceptual framework of what he considers as the nature of disciplinary scientific knowledge needed to help prospective teachers achieve high literacy, thus allowing them to transform their knowledge into forms attainable by the students without severely distorting that knowledge. He characterizes this disciplinary scientific knowledge as having three major components: structure, function and development.

Teachers' knowledge and understanding of the facts and concepts of science should be enriched with knowledge of the structure of the discipline. The structure refers to the relationships among scientific facts, concepts and procedures. It stands for the organizing principles about which facts and principles are interwoven in a dynamic fashion. Mastery of this knowledge allows teachers to integrate and "reorganize their knowledge and make it accessible to students" (Anderson, 1987, p. 10). This knowledge may serve as a precursor to understanding the empirical and holistic nature of science.

The function relates to the social and personal activities that knowledge of science prepares the individual to do. It is with such knowledge that the teacher can relate science to the everyday life activities and experiences of students, thus making science relevant to them. It also implies awareness of the societal impact of science, thus allowing the teacher to deal with this valued aspect of science education. This knowledge relates to the public nature of science.

Finally, the development of knowledge can be understood as the historical process through which knowledge assumed its current dynamic form. Otherwise it can be thought of as the way knowledge develops in individuals. This latter aspect is adequately reflected in knowledge about children's alternative conceptions in science and the way these conceptions develop. Knowledge of the development of science allows the teacher to look for alternative forms of understanding of concepts that are too difficult or abstract to be within students' reach. The teacher can thus present the concept at a level that matches the developmental level of the student. This aspect of Anderson's (1987) characterization of scientific knowledge seems to be most intimately linked to the tentative, probabilistic, unique, replicable, humanistic and historic nature of science.

So it can be seen that inherent to the knowledge of the structure, function and development of science as formulated by Anderson (1987) is an understanding of the nature of scientific knowledge. As such Shulman's knowledge base specific to the sciences can now be defined as possessing deep knowledge and understanding of the structure, function and development of science, and a deep understanding of the nature of science.

Anderson's (1987) framework serves well to explicate Shulman's (1987) knowledge base related to science teaching. His notion of the structure of the discipline and nature of science subsumes the deep understanding of the facts, principles and procedures of science, as well as of the processes involved in the production and validation of scientific knowledge. By adding the two dimensions of the function and development of science, Anderson also captures substantial parts of Shulman's PCK. These two dimensions subsume knowledge of the history of the discipline, students' alternative conceptions as well as knowledge of alternative representations of scientific concepts. Anderson's formulation allows the teacher to match instruction to the developmental level of the learner and meet his/her individual needs.

Adequacy of the Academic Preparation of Science Teachers

Secondary science teacher preparation programs commonly include university studies at the respective science departments leading to a Bachelor in Science followed by a year of post graduate training at the department or school of education leading to a Teaching Diploma (Arzi, White, & Fensham, 1987) or teacher certification. Several science educators believe that the academic preparation of secondary science teachers, with its present form and emphases, does not adequately prepare science teachers to teach for conceptual understanding of science (e.g., Anderson, 1987; Arzi et al., 1987; Shulman, 1987; Stoddart, Connell, Stofflett, & Peck, 1993; Stofflett & Stoddart, 1994).

The traditional, didactic pedagogy to which teacher candidates are exposed in university science courses serves only to equip them with minimal conceptual understanding of their science disciplines (Duschl 1983; Gallagher 1991; Pomeroy, 1993; Tiglner ,1990). Teacher candidates leave college science courses with a very limited knowledge of the structure, function and development of their scientific disciplines and also show a limited understanding of the nature of science (Gess-Newsome & Lederman, 1993; Nordland & Devito, 1974; Stoddart et al., 1993; Stofflett & Stoddart, 1994). Over and above, many of them hold serious alternative conceptions about the science content they are supposed to teach. These alternative conceptions are often similar to those held by their younger students (Anderson, Sheldon, & Dubay, 1990; Bishop & Anderson, 1990; Stoddart et al., 1993). So typically teacher candidates enter teacher education programs with an established form of low literacy. Moreover, teacher candidates graduate from the science departments having developed a strongly held pedagogical conception of science teaching. Stofflett and Stoddart (1994) notes that such a conception is typically that of teacher-centered lectures, demonstrations and textbook readings.

Teacher education programs do not usually challenge the strongly held misconceptions in content and pedagogy that their prospective teachers bring along. Teacher educators focus on helping student-teachers learn *how* to teach, and not *what* to teach (Stoddart et al., 1993; Stofflett & Stoddart, 1994). This is achieved by exposing student-teachers to general pedagogies of teaching and classroom management techniques. No attempts are made to upgrade student-teachers' knowledge of the content of their disciplines. And although some programs focus on developing student-teachers' conceptions of the nature of science, they do little to help them develop the knowledge and understandings necessary to transform such conceptions into actual practices inside the classroom (Gallagher, 1991). Teacher education programs seem to do little to upgrade student-teachers' knowledge of the structure, function and development of their discipline. It can thus be concluded that prospective science teachers leave teacher preparation programs with limited understanding of the valued aspects of what is supposed to be the disciplinary knowledge they need for teaching science.

Anderson's (1987) explication of Shulman's (1987) knowledge base may serve as a sound theoretical basis for characterizing the extensive knowledge base needed for good science teaching. This may have important implications on the assumptions that guide curricular development and reform of science teachers preparation programs. Accessing and describing teachers' disciplinary knowledge may serve as a first step toward that end.

The purpose of the present study was to describe the disciplinary knowledge of a group of science teachers. This knowledge was characterized in terms of the teachers' knowledge of the structure, function and development of their scientific disciplines, and their understanding of the nature of science. This knowledge was also related to such variables as the teachers' level of education, their years of teaching experience and the grade level(s) they teach.

Method

Participants

Twenty female inservice science teachers were selected to participate in the study. All teachers were graduates of the American University of Beirut (AUB), Beirut, Lebanon. All of them were teachers at private schools where English is the language of instruction. Their ages ranged between 21 and 45 years (with a median age of 31 years). All teachers held Bachelors degrees. Three of the participating teachers majored in physics, six in chemistry and eight in biology. The remaining three teachers majored in medical lab technology, agriculture, and pharmacy respectively, but all three had biology as a minor field of study. Five teachers held a Master of Science degree: two in physiology, one in microbiology, one in physics and one in agriculture. Ten of the participating teachers also held a Teaching Diploma (T. D.) in Science Teaching awarded by the Department of Education at AUB. The teaching experience of the selected teachers ranged between 1 and 19 years (with a median of 4 years). They taught intermediate and/or secondary grades (one teacher taught elementary grade levels). Of the 20 teachers selected only 17 completed all phases of the study. Three teachers left abroad before the study was concluded. Teachers in the sample reflected the enrollment of students in the various science departments at AUB as well as the enrollment of student-teachers in science methods courses at the Department of Education of the same university during the past few years.

This purposive sampling (Bogdan & Biklen, 1982) was used because it best served the purpose of this study. This sample was by no means intended to be representative of any larger population of science teachers.

Instruments and Procedures

The study's main feature was that of thick descriptions. Three different methods were used to generate data for the study. A modified version of the Views on Science-Technology-Society questionnaire (Aikenhead, Ryan, & Fleming, 1989) was used to assess teachers' understanding of the nature of science. Concept mapping was employed to measure teachers' knowledge of the structure of their scientific disciplines. Finally, clinical interviewing was used to assess teachers' knowledge of the function and development of their disciplines.

Views on Science-Technology-Society (VOSTS) Questionnaire

VOSTS was developed by Aikenhead, Ryan, and Fleming (1989). The instrument allows respondents to express their own viewpoints on a wide range of topics related to science. The instrument is an inventory of 114 multiple-choice items. Each item consists of a statement with several related reasoned viewpoints or positions. The items address topics related to defining science and technology, the external and internal sociology of science, as well as the epistemology of science. VOSTS items also relate to a wide range of Science-Technology-Society (STS) issues.

The version used in this study comprised 22 items that related to the nature of scientific knowledge. Since VOSTS is an inventory, selecting any number of items needed to investigate a certain science-related issue is appropriate (Aikenhead & Ryan, 1992). The items chosen specifically addressed the following components of the nature of science: the nature of observations, scientific models and classification schemes; the tentativeness of scientific knowledge; precision and uncertainty in scientific knowledge; logical reasoning in science; and the epistemological status of scientific knowledge. This epistemology relates to scientific assumptions, values in science, conceptual inventions in science (hypotheses, theories and laws), scientific method and consensus making in science. Also addressed is the issue of paradigms versus coherence across the various scientific disciplines. Moreover, although developed for 16 and 17-year old students, "VOSTS items have been used successfully with university students and with teachers" (Aikenhead & Ryan, 1992, p. 489). Fleming (1988), and Zoller, Donn, Wild, and Beckett (1991) successfully used the VOSTS questionnaire to assess science teachers' views and beliefs on STS related issues.

As the instrument was developed in the Canadian context, a group of science education students at AUB read the instrument and evaluated its content and appropriateness for the Lebanese setting. The modified version of the instrument was also pilot-tested on a randomly selected sample of 10 students who earned a Bachelor of Science from AUB in July, 1994. The pilot test's main aim was to assess university students' understanding of the items and the wording of the viewpoints. The evaluators' and respondents' feedback was positive. A few minor changes were recommended. These changes amounted to replacing some unfamiliar terms in two statements and in a few viewpoints with more familiar synonyms.

In addition, the selected VOSTS items were modified to become more flexible. On the original version of the instrument, each VOSTS item ends with the same three statements: "I don't understand", "I don't know enough about this subject to make a choice" and "None of these choices fits my basic view point". In the version that was used in this study, the final choice appeared as: "None of these choices fits my basic view point. My basic viewpoint is:" and the respondent was provided with space to express any viewpoint he/she deemed more appropriate.

All teachers were administered the modified version of VOSTS questionnaire. Teachers completed the questionnaire overnight in the privacy of their own homes. Most reported that it took them about one hour to respond to the 22 items selected.

Concept Mapping

Concept mapping was used to assess teachers' knowledge of the structure of the discipline. Concept mapping has been employed by researchers to assess structural knowledge at one point in time for purposes of comparing individual learners or groups of learners (e.g., Hoz et al., 1990; Markham et al., 1994) and to tap changes that occur in cognitive structures as a result of instruction and time (Markham et al., 1994; Novak, 1990). Markham et al. (1994), Wallace and Mintzes (1990), and Winitzky, Kauchak, and Kelly (1994) examined the concurrent validity of the concept map as a tool for assessing cognitive structures. The researchers concluded that there exists "a potentially strong relationship between the complexity of cognitive structures as revealed in concept maps and the extent of . . . meaningful knowledge possessed by the learner" (Wallace & Mintzes, 1990, p. 1045). As compared to other methods (e.g., paper and pencil tests, card sort tasks, etc.), the researchers found concept mapping to be the only technique to assess not only what the learners know but also how they come to organize their knowledge. Moreover, Anderson's (1987) definition of the structure of the discipline, and the theoretical bases on which Novak and Gowin (1984) built concept mapping as well as the kind of information explicated in concept maps, converge to the same point. Both aim at assessing and explicating an individual's depth of understanding of a set of concepts in a certain domain and of the relationships that link them together. This may serve as a possible theoretical background that may support the potential success of concept maps in tapping teachers' structural knowledge.

A structured concept mapping task was used in this study. Subjects first received training in concept mapping. In a one-hour session each subject was individually introduced to concept maps and key terms (concepts, propositions or relationships, cross-links, branches and hierarchy). Subjects were also introduced to the scoring criteria. This was followed by practice. Subjects were provided with a list of general science concepts and given the opportunity to construct a concept map. The map was then discussed and evaluated. Since each teacher was trained individually and to insure consistency in training, an explicit script was followed by the researchers.

After the training was concluded, each teacher and according to her disciplinary background was supplied with a list of 20 concepts relating to one of three topics. The topics selected were digestion; the chemistry of compounds, elements and atoms; and heat energy and temperature. The topics were presented to biology majors and minors, chemistry majors, and physics majors respectively. These topics were selected because they are taught both at the intermediate and secondary levels in the Lebanese curriculum with varying extents of depth and complexity. Science teachers are very likely to have taught one of these topics at one time in their careers. Moreover, these topics lend themselves to be related to the everyday life of students. In addition, students' alternative conceptions relating to these topics are documented in the literature (for example, Driver, Squires, Rushworth, & Wood-Robinson, 1994). The 20 concepts relating to each topic were chosen by the researchers and disciplinary experts. The three concept lists used were:

Biology: absorption of nutrients, bile from liver, chemical digestion, chewing, digestion, esophagus, gastric fluid, intestinal enzymes, large intestines, mechanical digestion, mouth, muscle action, pancreatic fluid, pepsin, peristalsis, salivary amylase, small intestines, stomach, tongue and teeth, and water.

Chemistry: atoms, atomic number, chemical formulas, chemical symbols, compounds, covalent bonds, double bonds, electrons, elements, energy levels, ions, ionic bonds, ionic compounds, mass number, molecules, neutrons, nucleus, protons, single bonds, and subatomic particles.

Physics: atoms, absolute zero, amount of substance, average kinetic energy, conduction, energy transfer, heat, internal energy, interparticulate forces, joules, Kelvin scale, kinetic energy, molecules, motion, matter, objects in thermal contact, potential energy, temperature, temperature difference, and thermal equilibrium.

Concepts in each list appeared in alphabetical order to insure that no hints whatsoever are given to the teachers as to any possible hierarchical relationship between the concepts. Participants were then asked to construct a concept map using the list of concepts provided and were explicitly instructed to construct maps reflecting their university level science knowledge on the topic concerned. The maps were expected to be as extensive and elaborate as possible. No time limits were set for constructing the concept map. However, teachers took between 45 and 60 minutes to construct and review their maps.

Clinical Interviews

Once teachers' knowledge of the structure of their disciplines was represented, the researchers proceeded to tap their knowledge of the function and development of science. This was achieved by using individual clinical interviews which were based on the concept maps generated by the teachers.

Knowledge of the function of the discipline was assessed by asking the teachers to explicate their knowledge of everyday life applications relating to the specific topics addressed in the maps, and/or everyday life applications relating to specific concepts that the teachers have mapped. Teachers were asked to be exhaustive and were to list as many everyday life applications as possible. This helped to reveal the teachers' knowledge of the relevance of the addressed science concepts to the everyday lives, interests and needs of their students.

Tapping knowledge of the development of science was achieved by using two approaches. The first was based on the assumption that knowledge of the development of the discipline allows the teacher to match the science content to be presented to the developmental level of the student. Teachers should be able to tailor and present science concepts without de-contextualizing those concepts, or presenting students with isolated and distorted conceptions that need be memorized (Anderson, 1987). This was achieved during the interview by asking each teacher about the changes she would make in her concept map if she were to teach the same set of concepts to students in an intermediate grade level. The teacher also had to justify any changes she would make. As the original map constructed by each teacher was supposed to reflect her university level knowledge of the topic addressed, teachers were expected to modify the structure, the complexity of the interrelationships and the levels and number of hierarchies in their maps in order to match it to the grade level assigned. The grade level chosen was the second intermediate where students are typically 12-year old. In the second approach each teacher was asked to explicate her knowledge of any alternative conceptions (or misconceptions) that students of the second intermediate hold about the topic addressed in the concept map. Were the teachers to find characterizing the alternative conceptions of 12-year old students not feasible because they did not teach this particular grade level, they were alternatively asked to list the alternative conceptions of the students in any grade level(s) that they teach. Again teachers were asked to be exhaustive.

The clinical interviews were semi-structured. In the first part of the interview, the researchers reviewed with the teacher the map that she had constructed. The objective was to clarify any ambiguities in the map and give the teacher a second chance to review the relationships that she had mapped between the given set of concepts. Next, a set of three basic questions guided the interview. These questions were:

1. The map you have constructed reflects your university level knowledge, and you can see that a concept map can be used to guide instruction. If you were to teach the same set of concepts to students of the second intermediate, i.e. 12-year old students, what would you change in this concept map? and why?
2. It is believed that students come into the classroom having --out of their everyday life experiences, built some conceptions about the natural world around them including ideas related to the topic/concepts that we have been discussing. Do you know about any such ideas that 12-year old students (or students that you teach) bring with them into your classroom and that relate to the concepts at hand?
3. Relating science to the everyday lives of the students is very important both to get them interested and to make studying science more meaningful for them. I would like you to list as many of the examples that you use to relate the topic/concepts at hand to the everyday life of your students as you can.

However, digressions were very common and the researchers often re-worded the above questions and used many other questions to follow the teachers' lines of thought or when deemed important. For example, one digression that was recurrent in interviews with biology teachers was asking them about proper diet and food groups (for example: what types of nutrients are found in "Labneh"? Labneh --a dairy product, is a traditional and very common Lebanese dish). This was necessary as most of the biology teachers found it relatively difficult to give everyday life examples related to digestion. When biology teachers were not able to relate digestion as a process to the everyday lives of their students, other questions were used. Two examples of such questions were:

1. Every time a 12-year old student eats a double burger, French fries and drinks a large cup of Pepsi for lunch, he/she almost always hears that this food is not healthy. What would you tell him/her?
2. Children are often told that they should not drink water directly after having lunch. Is this really problematic? What would you tell your students?

The above examples were by no means exhaustive but were intended to give examples of the digressions that occurred in the interviews.

Data Analysis

Data analysis was conducted by one of the researchers. An independent and blind analysis was then performed by the second researcher to corroborate any findings or conclusions.

Analysis of the Responses to the VOSTS Items

Teachers' responses to the VOSTS items were categorized as informed or naive. Views that converge with the more recent conceptions of the nature of science advanced by such philosophers of science as Kuhn were characterized as informed. Alternatively, views were categorized as naive if they converged with those views advanced by logical positivists. Logical positivists suggest that science is directly related to reality, and that it strives to uncover absolute truths independent of the scientists' personal, social and cultural characteristics. Moreover, they suggest that objectivity in science is only guaranteed by the scientists' use of the inductive scientific method (Ryan & Aikenhead, 1992).

Viewpoints on each item used in the study were categorized as reflecting informed or naive conceptions. The researchers carried out the categorization independently. Full agreement on classifying all viewpoints was the criterion to include an item for final analysis. Only one item relating to scientific theories was excluded from the analysis as agreement on categorizing some viewpoints was not reached. The same categorization was done for those ideas that were expressed by the science teachers when they decided that none of the provided viewpoints on a certain item expressed their own beliefs. Next, the percentages of informed and naive views for all the items were calculated for each teacher.

Scoring the Concept Maps

Three expert maps were constructed by reference to concept maps in disciplinary textbooks (e.g., Hewitt, 1987; McLaren, Rotundo, & Gurley, 1991; Towle, 1993). The maps were reviewed by disciplinary experts.

A modified version of a scoring scheme used by Hoz et al. (1990) was employed to score the maps. Four dimensions of the constructed maps were assessed. These were disciplinary validity, congruence, salience and central concepts.

The nature of the links in a particular knowledge structure have three dimensions: the correctness of the links (validity), the extent to which the substantial links are actualized and the abundance of the valid links. Substantial links are mandatory links as depicted on the expert maps. In the present study all links on the expert maps were considered substantial.

The validity of the links was assessed on a four level ordinal scale (0 to 3). The links were classified as valid (having levels 3 or 2), or invalid (having levels 1 or 0). Judgments were made by comparison to the expert maps. Scores were assigned as follows: valid (3 points) for a correct, precise and clearly stated link; moderately valid (2 points) for a correct, sensible but incomplete link; partially valid (1 point) for a general and indirect link lacking in certain aspects; or invalid (0 points) for an incorrect link. It should be noted that a link that represented a negative instance --

i.e. the lack of a relationship between two concepts, was considered not valid unless this relationship was substantial and was depicted on the expert maps. An example of such negative instances was that "water does not need chemical digestion". The simple fact that a link between the two concepts (water and chemical digestion) is not mapped implies the lack of that relationship. The validity of the knowledge structure was computed as the percentage of the sum total of the validity scores on a concept map out of the maximal validity scores as derived from the expert map.

To measure the extent to which the substantial links were actualized, congruence scores were used. Congruence was computed as the number of the valid, substantial links in a map divided by the number of all substantial links as derived from the expert map.

Salience measures the abundance of valid links. Salience was computed as the number of valid links divided by the number of all links in a teacher's map.

In a knowledge structure there are central concepts. A central concept was defined as one having substantial, valid links with at least 15% --i.e. with at least three concepts, of the 20 concepts in the concept map. The extent to which central concepts were actualized was calculated as the number of central concepts in a teacher's map divided by the total number of central concepts as derived from the expert maps.

An additional score was also produced for the map as a whole. The scoring scheme focused on the complexity of the knowledge base and the structure of the scientifically acceptable links depicted on the map (Wallace & Mintzes, 1990). Scoring focused on the number of relationships (one point for each valid proposition), hierarchy (five points for each valid level of the hierarchy), branchings (one point for each branch with valid links) and cross links (ten points for each valid cross link) represented in the map. Then, the scores were compared to a score derived from the expert map.

To insure the reliability of the scoring, the concept maps were first independently scored by the researchers. Then one physics, two chemistry and three biology concept maps were randomly selected from among the seventeen maps. These maps were blindly scored by three disciplinary experts according to the scoring criteria described above. The correlation (Pearson r) between the judges' scores was 0.96 for the biology concept maps and 0.98 for the chemistry and physics concept maps.

Clinical Interviews

All interviews were audio-tape recorded and transcribed for analysis. The criterion used to evaluate the everyday life examples given by the science teachers was relevancy. The acceptable examples or everyday life applications were those related to the students' lives and realm of experiences. The misconceptions identified by the teachers were considered valid if they were to converge with those documented in the literature. Otherwise the misconceptions suggested by the teacher were expected to converge with the definition of alternative conceptions presented by Fowler and BouJaoude (1987) who define an alternative conception as an "inaccurate understanding of a concept [or proposition], . . . wrong classification of concept examples, confusion between different concepts, improper hierarchical relationships, over- or under-generalizing of a concept [or proposition], or improper application of propositions" (p. 4). The frequencies of valid everyday life examples and alternative conceptions provided by each teacher were tallied.

Moreover, teachers' responses to the researchers' questions about changes they would make in their concept maps were these maps to be used to guide instruction with 12-year old students were categorized by discipline (biology, chemistry or physics) and reported.

Finally, teachers were grouped according to the variables of interest: the teachers' level of education, their years of teaching experience and the grade level(s) that they taught. Two groups were selected to reflect the level of education: T. D. and No T. D. Teachers in the 'T. D. group' held a Bachelor of Science and a Teaching Diploma. Those teachers in the 'No T. D.' group held a Bachelor or a Master of Science. Six groups were used to categorize teachers according to their teaching experience, while four groups were used to categorize them according to the class level(s) taught (elementary, intermediate, secondary, and intermediate and secondary grade levels). Next, the percentages of informed and naive teachers' views on the nature of science, as well as their scores on the concept maps and the numbers of everyday life examples and alternative conceptions that they provided were averaged for the above groups. Relationships were then sought.

Results

The disciplinary knowledge of the science teachers was lacking in all respects. Teachers' held many naive views about the nature of science and showed inadequate knowledge of the structure, function and development of their disciplines. These components of disciplinary knowledge did not relate to the teachers' level of education, their years of teaching experience or the class level(s) they taught.

The Nature of Science

While all of the teachers expressed some views that are in line with the more recent conceptions of the nature of science, they all held many naive views. The percentages of informed views ranged between 38% and 67% while the percentages of naive views ranged between 33% and 62%. The average was 50% for informed views, 48% for naive views and 2% for 'no position'.

Averages of the percentages of informed and naive views for the teacher groups categorized according to the variables of interest are presented in Table 1 (see Appendix). No major differences were evident between the various groups. A summary of all participant teachers' views on the nature of science is presented below.

Almost all of the teachers (94%) believed that scientists follow a recipe --the so called scientific method, in their investigations. A sizable majority (88%) believed that sticking to the scientific method differentiates the competent from the incompetent scientist. The teachers thus overlooked the role of creativity and imagination in science. In fact, when the term "scientific method" appeared on the items that addressed the topic of "scientific approaches to investigation", all the teachers expressed naive views. However, when responding to other items that addressed the same topic without explicitly stating the term "scientific method", almost all the teachers (94%) adopted the more informed view that scientific activities are not completely logical and sequential. It seems that teachers did not give much thought into items where the term "scientific method" appeared. They seemed to have directly adopted the naive views propagated in school science textbooks about this issue.

Moreover, many teachers (47%) did not show an adequate understanding of the humanistic nature of science. They thought that scientific models are copies of reality rather than human inventions. The majority of teachers (82%) did not appreciate the role of theories in guiding scientific investigations. Recognition of the existence of paradigms was replaced with a belief in the universality of science. Many teachers (71%) did not demonstrate an adequate understanding of the theory-laden nature of scientific observations. That scientists work and interpret scientific "facts" from within certain frames of reference was not well understood. A majority of teachers (59%) also adopted a simplistic and hierarchical relationship between the various scientific constructs by which hypotheses become theories and theories become laws depending on the availability of supporting evidence. The fact that these constructs are different types of ideas was not grasped. Moreover, many teachers (59%) thought that scientists do not make assumptions in their work, or that they otherwise research any assumptions to prove them "true" before commencing their work.

Knowledge of the Structure of the Discipline

Teachers' knowledge of the structure of their disciplines was not elaborate. This was reflected in the relatively low scores on the validity, congruence, salience and centrality of concepts dimensions, as well as the low holistic scores on their concept maps.

Validity, Congruence, Salience and Centrality of Concepts

Teachers' scores on the four dimensions of their concept maps represent percentages derived by comparing each of these four dimensions on the teachers' concept maps to those on the expert maps.

Validity scores measure the scientific accuracy of the teachers' concept maps. Validity scores ranged between 37 and 90. The majority of these scores (71%) were below 65 and reflected a relatively inaccurate knowledge base. Only one teacher had a validity score of 90. Salience reflects the percentage of the valid links expressed by each teacher out of all the links provided by the teacher herself. Fifty eight percent of the teachers scored between 90 and 100 and 24% scored between 75 and 90. These high salience scores indicate that teachers only produced those parts of their knowledge of which they were confident. However, the majority

(82%) of the congruence scores --which measure the extent to which substantial or mandatory links were actualized on the teachers' maps, were below 65. This indicates that the parts of knowledge that the teachers chose to represent on their maps did not fit what the disciplinary experts deemed important.

A number of cognitive psychologists suggest that understanding a domain of knowledge is equivalent to understanding the relationships between the central concepts in that domain (Winitzky et al., 1994). Teachers were not successful in identifying the central concepts in the topics used in this study. The centrality of concepts score represents the percentage of central concepts on the teachers' maps out of the total number of central concepts on the expert maps. The scores on central concepts ranged between 15 and 92. Fifteen scores (88%) were below 69. This reveals that teachers' knowledge structures comprised at best isolated and non-integrated chunks of information.

Holistic Scores for the Concept Maps

To compute a holistic score for each of the concept maps, the number of valid links, cross-links, branches and valid levels of the hierarchy on each concept map were counted and scored. The scores were summed to derive a raw score for each map as a whole. This score was then compared to the raw score derived from the expert map and reported as a percentage. Table 2 (see Appendix) presents these frequency counts, scores and percentages for teacher and expert maps categorized by disciplinary background (biology, chemistry or physics).

What is evident from examining Table 2 is the markedly small number of cross-links that the teachers have mapped. Compared to 24 cross-links on the expert biology map, seven of the nine biology teachers mapped less than 7 cross-links. Compared to 12 cross-links on the chemistry expert map, four of the six chemistry teachers mapped 4 or less cross-links. Finally, compared to

10 cross-links on the physics expert map, one teacher mapped 5 cross-links, while the other mapped only 1. It seems that the teachers were not able to see beyond the simple and direct relationships that connect their concepts. This may reflect the lack of knowledge of a rich array of relationships between concepts since cross-links reflect the degree of knowledge integration.

A quick look at the number of the valid levels of the hierarchy (see Table 2) on the constructed maps may be reassuring. The numbers in most cases approximate the number of levels of the hierarchy on the expert maps. But a closer look at the way these hierarchies were constructed raises important questions. On the expert biology map, the levels of the hierarchy were meant to reflect the parts of the digestive tract. This is one of the more simple but rather powerful modes of organizing the given set of concepts about digestion. The learner can follow the movement of food, the mechanical and/or chemical digestive activities taking place as well as the chemical agents involved at the level of each organ of the alimentary tract. Of the nine biology teachers, only four used the digestive tract to organize their hierarchies. As far as the chemistry concepts are concerned, only one of the six chemistry teachers used the mandatory compounds, elements, atoms and sub-atomic particles hierarchical relationship that was utilized to arrange the levels of the hierarchy on the expert map. Finally, the hierarchical relationships between motion and inter-particulate forces and the various forms of energy of atoms and molecules (kinetic, potential and internal energies) as represented on the expert physics concept map were absent from the maps constructed by the two physics teachers. Overall, the hierarchies constructed by the teachers did not reflect an elaborate subsumption of the relationships between the given sets of concepts.

Table 3 (see Appendix) presents teacher groups' average scores on validity, congruence and central concepts and their holistic scores. The only difference noteworthy is that teachers in the

T. D. group scored better on all of the above measures than did teachers in the No T. D. group. Other differences, such as the low scores of the teachers with 7 and 8 years of teaching experience and those teaching secondary grade levels seem to reflect the low scores of teacher #1 rather than any other possible reason especially as there are only two teachers in each of these groups. No other important differences were evident neither between nor across the groups.

Knowledge of the Function of the Discipline

The number of valid everyday life examples or applications given by each teacher are presented in Table 4 (see Appendix). Four teachers (24%) were not able to give a single valid everyday life example of the topic or concepts addressed in their maps. Nine teachers (52%) gave less than five examples.

Teachers had a difficult time coming up with everyday life examples. For instance, one chemistry teacher was able to give only a single example of ionic compounds, namely sodium chloride (table salt). When asked for another everyday life example, and after a long pause, the teacher said: "I don't usually give an example . . . I don't relate it to something they see in life" (teacher # 11). Another chemistry teacher gave magnesium chloride and silver nitrate as examples of ionic compounds. However, she could not tell where students may encounter such compounds in their lives (teacher # 4).

Moreover, several teachers (e.g., teachers #1, #8 and #16) confused everyday life examples of concepts with analogies or using familiar things to explain certain concepts. For example, when asked to give everyday life examples of atoms, teacher # 16 said: "I tell my students that the nucleus is like a small, heavy iron ball situated at the center of a much larger plastic ball representing the electron cloud". Other teachers gave incorrect examples. For instance teacher #

16 said that lemon juice contains acetic acid (which is found in vinegar), while in fact it contains citric acid.

Many teachers were not able to explain the everyday life examples that they provided. For instance, one biology teacher listed sayings from everyday life related to digestion such as "don't skip breakfast, don't eat then go to sleep, have a walk after you have a meal, etc." However, when asked how would she explain these to her students and relate them to digestion as a process, she said: "I am really not good at explaining these" (teacher # 14).

When teachers were not able to provide everyday life examples, several questions were used to assess their ability to explain or use such examples in their teaching. The physics and chemistry teachers were asked to provide a simple everyday life experience that can be used to convince students of the presence of particles (atoms and molecules). Only one out of eight teachers was able to give an appropriate example (an opened perfume bottle). The biology teachers were asked whether they thought that burgers and French fries were not healthy for their students. Four of the biology teachers thought that this meal is not problematic by itself. Three other teachers thought that this diet may cause digestive problems. When asked whether it is problematic to drink water directly after meals, five of the biology teachers thought that this slows digestion because acids in the stomach are diluted by the water. Three other teachers thought that this is not problematic at all. Regardless of the disciplinary accuracy of responses to these questions, it can be noted that teachers lack a common knowledge base on such issues. Their answers are sometimes contradictory. For instance, biology teachers could not agree on what nutritive components are found in milk.

Only one teacher (teacher # 6) was able to demonstrate knowledge of a wide range of everyday life examples and applications and provided about 18 examples and was ready to give many more. Moreover, this teacher was also capable of explaining the everyday life examples she gave in simplified ways. Examples here include why should students not swim directly after eating, or avoid having a heavy meal before going to sleep, etc. When it came to diet and nutrition, the teacher was able to tell what nutritive ingredients are found in many traditional Lebanese foods and what alternatives types of foods have similar nutritional values. Among the many examples given, the teacher said that she usually asks her students to avoid chocolate bars having sucrose. Being a double sugar, sucrose needs to be digested first and cannot be directly absorbed. As such it stays in the mouth and causes damage to the teeth. Students can alternatively have candy bars with the mono-saccharide glucose, which can be directly absorbed and as such causes much less problems. The teacher was able to give many commercial brand names of chocolate bars that contain glucose only.

No important differences or trends were found when the numbers of everyday life examples provided by the teachers were averaged for teacher groups categorized according to the variables of interest.

Knowledge of the Development of the Discipline

Teachers did not demonstrate an adequate understanding of the developmental nature of science, or the developmental nature of students. Teachers failed to see that most science concepts can be taught in one form or another at any grade level. On the other hand, teachers were not knowledgeable of their students' alternative conceptions regarding the target topics and concepts.

Changes in the Concept Maps

Of the nine biology teachers, three believed that no changes, neither in the structure of the map nor in the complexity of the links, were necessary. A fourth teacher believed that the concept of chemical digestion need only be presented in a simpler way. Four more teachers said they would omit some concepts, focus on mechanical digestion and present the concept of chemical digestion in a simplified way. The concepts omitted were different combinations of: peristalsis, salivary amylase, gastric fluid, pepsin, bile and intestinal enzymes. No two teachers omitted the same set of concepts. Teachers thought that students at the second intermediate grade level lack the prior knowledge necessary to present them with the concept of enzymes and their role in chemical digestion. And indeed helping students to realize the difference between mechanical and chemical digestion without going into the details of the chemistry of enzymes and chemical change was the major problem for these four biology teachers. One said that she would explicitly tell her students that "you will see this [chemical digestion] later" (teacher # 5). The other three attempted to provide simple explanations to help students differentiate mechanical from chemical digestion. The first teacher suggested that in chemical digestion "certain kinds of liquids . . . act in a certain chemical way at a microscopic level" (teacher # 2). The concept of chemical change, however, went unexplained. The second teacher suggested that in mechanical digestion food is "broken down" while in chemical digestion food is "reduced" (teacher # 3). This may be problematic as both terms have very close meanings. The third teacher gave a more accurate picture when she said that she would replace mechanical digestion with "break down into small pieces" and chemical digestion with "changing substances into other things" (teacher # 12), but she failed to verbalize the idea further or to support it with activities or demonstrations. Only one of the biology teachers (teacher # 6) was able to give an alternate form by which to help students distinguish between chemical and mechanical digestion. For that purpose she would use a rather simple but powerful demonstration. With a scissors, she would cut a sheet of paper into small pieces. This is similar to mechanical digestion, although the paper (or food) is broken down into small pieces, it did not change, it still is paper. Now she would put the pieces in an ash tray and burn them. The paper now changes into something else: ashes, from which the paper can no longer be recovered. This is similar to chemical digestion where food is changed into 'something else'.

All six chemistry teachers maintained that they would keep the same structure of their maps. Two of the teachers believed that all of the concepts and relationships they mapped are teachable to 12-year old students. The other four teachers suggested that they would omit some concepts. The concepts eliminated were: subatomic particles (including electrons, protons and neutrons), energy levels, ions, ionic bonds, covalent bonds, single and double bonds and chemical symbols. Again no two teachers agreed on the set of concepts to be eliminated. None of the chemistry teachers suggested that these concepts can be simplified and presented to students.

At the beginning of the interview the two physics teachers suggested that they would keep the same structure but simplify the concepts for 12-year old students. However, they were not sure about the form in which the concepts can be presented. As a result, they suggested omitting some of the concepts such as inter-particulate forces and absolute zero. They also thought that students cannot handle the labels (not the concepts): potential, kinetic and internal energy.

Overall, five teachers (29%) made no changes in their maps. This may indicate that they are not aware of the developmental nature of their students' thinking. Five more teachers (29%) kept the same structure and omitted several concepts from their maps. They found no problem in presenting concepts as isolated labels, independent of other intimately related concepts. Many did not seem to believe that most science concepts can be taught at any level in one form or another. While six more teachers (36%) thought that some concepts need to be simplified in order to be attainable by 12-year old students, they were not able to articulate those simplified forms.

Each teacher gave one or more reasons for the changes on her concept map. Some teachers believed that age is the overriding factor behind the changes, others thought that the effect of prior knowledge outweighs that of age. This latter group of teachers suggested that given enough time they could teach any set of concepts to 12-year old students. Still other teachers suggested a combination of age, prior knowledge and the difficulty level of the concepts as the reason behind the changes they made. The fact that different justifications were given may suggest the lack of a consistent view among the teachers on this issue.

Alternative Conceptions

Overall, the number of valid alternative ideas provided by the teachers was strikingly small (see Table 4). Ten teachers (59%) said they knew of no misconceptions or spoke of things they had mistaken for misconceptions.

Teachers did not have an adequate understanding of alternative conceptions. Many were unaware of the fact that such conceptions develop long before children receive any formal science teaching. Some teachers believed that students' misconceptions on the topics discussed should be rare since students are introduced to such concepts for the first time (e.g., teachers #4 and #9). Teachers also were not aware that such conceptions persist and often survive formal science teaching. One teacher believed that upon explaining the concepts, her students "go out of these misconceptions by realizing what is true and . . . what is wrong" (teacher # 14). Another teacher (teacher # 1) believed that because the study of the concepts discussed is covered in all the intermediate classes, students were unlikely to develop any misconceptions. Those teachers who said they knew about their students' misconceptions found a hard time enumerating them. One teacher said "I always encounter misconceptions . . . but I don't have any clear examples in mind" (teacher # 17). Moreover, an overwhelming majority of the misconceptions that the teachers listed were confused with isolated misinformation or lack of information. Examples are that students "don't have any idea about chemical digestion" (teacher # 6) or that "they don't know anything about enzymes" (teacher # 5). Other teachers thought that when students have difficulties in understanding some concept that they were explaining then the students have a misconception (teachers #4, #9 and # 11). One teacher (teacher # 16) said that although she had studied about misconceptions during her T. D. program, she had no idea about her students' naive ideas nor did she look for them. She preferred to think of her students as "blank, their minds are completely blank" and she usually starts from there and not from what the children already know.

Again, no important differences or trends were found when the numbers of alternative conceptions provided by the teachers were averaged for teacher groups categorized according to the variables of interest.

Finally, it should be noted that teachers who demonstrated competence in one dimension of their disciplinary knowledge did not do equally well on the others. Moreover, the most important finding is that teachers' scores did not relate to their level of education. The scores of the 'T. D.' and 'No T. D.' groups did not differ on all the dimensions except the better scores on the concept maps for the T. D. group. This may support what has been suggested about the inadequacy of teacher training programs in preparing prospective science teachers who are able to help their students achieve an attainable form of high scientific literacy.

Discussion

Shulman (1987) calls on teacher preparation programs to emphasize teachers' content knowledge. These programs can no longer limit their efforts to content-free domains of pedagogy or effective classroom management behaviors. It follows that teacher preparation programs should aim to enhance prospective teachers' knowledge of the structure, function and development of science, and their understanding of the nature of science.

Prospective teachers need ample opportunities to reflect on and to learn --or relearn, their science content in deeper and more connected ways. They need to integrate their science content into a structural framework that makes it more accessible and understandable to them in the first place. Prospective teachers should be helped to connect university science with everyday experiences to further their knowledge of the function of science, and should be helped to develop knowledge of students' naive understandings and how these understandings affect students' learning. Moreover, prospective teachers need to develop understanding of the nature of science (Teacher Preparation in Michigan, 1994). But what is more important is that teacher preparation programs should provide prospective teachers with experiences on how to use their knowledge and understandings to help their students develop adequate understandings of science (Lederman, 1992; Pomeroy, 1993; Tiglner 1990).

However, reform of teacher education seems to be guided by other agendas. The Carnegie Task Force (1986) and the Holmes group (1986) recommend higher standards for entry into teacher education programs including a greater number of years in higher education in the specific content areas and higher grade point averages. They also suggest that teacher preparation should include prolonged programs in theoretical and practical preparation.

Nonetheless, such recommendations seem to put reform efforts on a circular track. On the one hand, requiring teacher candidates to take more of the didactic university science courses is unlikely to enhance their weak understanding of their content. This measure will only result in teachers having a more strongly held linear and fragmented conception of their subject matter (Gess-Newsome & Lederman, 1993; Stoddart et al., 1993). On the other hand, requiring student-teachers to take more courses at the department of education and to spend extended internships in cooperating schools would only serve to expose them to more content-free, generic education courses at that department and familiarize them at the schools with instructional methods that reformers are eager to change and for longer periods of time.

Alternatively, "[w]hat is needed is a new form of teacher education where the development of subject matter knowledge and pedagogy are integrated" (Stoddart et al., 1993, p. 232). Reform efforts that stress helping students to develop conceptual understanding of science through innovative curricula and methods of instruction may fail if such recommendations on teaching and learning of science are not equally applied to teacher education (Nordland & Devito, 1974; Stofflett & Stoddart, 1994).

It can be rightly argued that 'it takes the whole university to prepare a teacher'. "[T]eacher education is the responsibility of the entire university, [and] not the schools or departments of education alone" (Shulman, 1987, p. 20). A joint effort between science instructors at the various disciplinary departments and science educators is needed to help the former become aware of the needs of preservice teachers and consequently to model their instruction to conform with these needs (Anderson, 1987; Gabel & Rubba, 1978; Tiglner, 1990; Zeitler, 1984).

Anderson (1987), however, recognizes that there are institutional and personal barriers to a coordinated effort between science professors and science educators. Meanwhile, and until such coordination is possible, science educators continue to advance suggestions aimed to enhance the preparation of science teachers. In this respect Gess-Newsome & Lederman (1993) suggest that distinct content-specific science methods courses in the various disciplines should replace the general, content-free science methods courses that are currently emphasized in science teacher preparation programs. Content-specific methods courses are necessary to help prospective teachers reflect on, articulate and explicate their knowledge of science and the way they are going to teach it.

However, while attempting to enhance teachers' knowledge base, teacher educators should not ignore student-teachers as active learners and should help them to examine their content knowledge and their beliefs about teaching and learning (Stoddart et al., 1993; Stofflett & Stoddart, 1994). Otherwise, when student-teachers are presented with effective approaches to science instruction, they may revert back to the traditional methods of teaching that they were exposed to in their school and university studies. The conceptual change approach should replace the modeling approach currently utilized in methods courses. Thus, in addition to shifting emphasis from disseminating the general pedagogies of teaching and classroom management techniques to developing student-teachers' disciplinary knowledge, content-specific methods courses should also adopt an alternative approach in presenting this knowledge. A process of conceptual change should replace modeling if student-teachers' firmly held conceptions in content and pedagogy are to be challenged and reconstructed.

Further research is needed to validate the characterization of the knowledge base for science teaching presented in this study. Research efforts in the near future should focus on investigating the relationship between the conceptualized components of the teachers' disciplinary knowledge and their classroom behaviors. The aim would be to test whether knowledge of these components does in fact translate into classroom practices that can help students develop the desired understandings of science. If this proves to be the case, researchers interested in teacher education should focus on the knowledge base that need be employed in any possible content-specific science methods courses. Certain science themes or major theories that permeate science teaching in the middle and high school levels can be identified and the disciplinary knowledge needed to teach these topics can be collated. The effects of teachers' having such a knowledge on helping students to develop conceptual understanding of science can be evaluated.

Finally, it should be noted that the classroom is a very complex place. The manifold realties and constraints that govern, and the conditions necessary for good teaching are far more varied to be controlled or met by knowledge of the four suggested components alone. This knowledge may well be a necessary condition for good teaching but it should not be thought of as sufficient. Other variables such as the classroom social and cultural environments and individual differences among students are important factors that need to be researched to further our understanding of the complexities that govern good teaching and learning inside the science classroom.

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Table 1

Average Percentages of Informed and Naive Views of Teacher Groups

Variable	n	Percentages		
		Informed	Naive	No position
Level of Education				
T. D.	10	48	51	1
No T. D.	7	54	45	1
Teaching Experience				
1 & 2 years	6	47	51	2
3 & 4 years	3	59	41	0
5 & 6 years	2	55	42	3
7 & 8 years	2	55	45	0
9 & 10 years	2	43	57	0
> 10 years	2	46	52	2
Class level taught				
Elementary	1	43	57	0
Intermediate	7	52	47	1
Secondary	2	43	54	3
Secondary & Intermediate	7	52	47	1

Table 2

Number of Valid Links, Cross-links, Branches, and Levels of Hierarchy of Participants' Maps

Map	Links	Cross links	Branches	Hierarchy	Raw score	%
Expert Biology	20	24	11	8	311	
Teacher # 2	13	6	10	7	118	38
Teacher # 3	20	3	12	6	92	30
Teacher # 5	18	0	13	8	71	23
Teacher # 6	17	3	13	5	85	27
Teacher # 12	17	6	12	7	124	40
Teacher # 13	17	10	11	6	158	51
Teacher # 14	18	5	15	6	113	36
Teacher # 15	18	3	13	6	91	29
Teacher # 17	18	12	13	8	191	61
Expert Chemistry	19	12	14	7	188	
Teacher # 1	13	0	12	7	30	32
Teacher # 4	19	4	14	6	103	55
Teacher # 8	20	2	13	8	94	50
Teacher # 9	19	7	16	6	135	72
Teacher # 11	21	8	9	7	145	77
Teacher # 16	17	4	11	6	98	52
Expert Physics	22	10	8	9	175	
Teacher # 7	17	5	4	8	11	63
Teacher # 10	20	1	7	10	87	50

Table 3

Average Scores on Concept Maps of Teacher Groups

Variable	n	%	Validity	Congruence	Central Concepts
Level of Education					
T. D.	10	52	64	56	59
No T. D.	7	38	50	45	39
Teaching Experience					
1 & 2 years	6	53	61	56	57
3 & 4 years	3	51	63	54	64
5 & 6 years	2	45	57	51	47
7 & 8 years	2	31	45	38	30
9 & 10 years	2	47	58	56	51
> 10 years	2	38	56	43	36
Class level taught					
Elementary	1	51	60	57	56
Intermediate	7	40	53	47	47
Secondary	2	35	44	41	23
Secondary & Intermediate	7	55	67	58	62

Table 4

Number of Valid Everyday Life Examples and Alternative Conceptions

Teacher	Everyday life examples	Alternative conceptions
1	2	none
2	none	none
3	2	none
4	7	2
5	none	none
6	18	none
7	4	2
8	4	2
9	6	1
10	3	1
11	4	2
12	none	1
13	none	none
14	1	none
15	2	none
16	7	none
17	2	none

STUDENT TEACHERS WITHIN CURRICULUM REFORM: DOES A LABEL MAKE A DIFFERENCE?

Joan M. Whitworth, Morehead State University

Introductory Remarks on the Importance of the Education of Teachers from the Pre-service Years and Continuing Throughout their Professional Careers.

> Educational change involves learning how to do something new. Given this, if there is any single factor crucial to change it is professional development. In its broadest definition professional development encompasses what teachers bring to the profession and what happens to them throughout their careers ... the educator as life-long learner is the key to future reform (Fullan, 1991, p.289).

Other researchers (Buttery, Haberman, and Houston, 1990; Sizer, 1987) have identified the need for reform in teacher education to go "hand-in-hand" with reform in the schools. But there is a minimal amount of research in teacher education, especially field experiences or student teaching. There exists a need to know what is occurring within the context of field experience and, also, a need to know what should be occurring (Guyton and McIntyre, 1990).

Teaching is a profession where aspiring practitioners enter the field with preconceived beliefs and conceptions about teaching and learning acquired during the 12 years or more they spent within the educational system. Lortie (1975) calls these prior experiences, where students form their ideas of what should go on in the classroom, the "apprenticeship of observation." What aspiring teachers learn from teacher education is determined, at least in part, by the knowledge and beliefs they bring with them into teacher education (Calderhead and Robson, 1991; Grossman, 1991).

This study is based on the philosophy that learning to teach, like all other learning, is constructive. It is a process of inquiry—the task of relating what one has encountered to one's current ideas (Strike and Posner, 1985). It focuses on the creation of a learning environment instead of concentrating on a body of facts (Borko and Putnam, in press).

According to cognitive theorists it is essential that an environment conducive for learning not be abstract and detached but closely connected with its physical and cultural contexts (West and Pines, 1985). For knowledge to be useful for teaching it must be linked to the context in which it is to be used. Methods classes, which present theory and associated teaching strategies detached from the classroom context, often are unsuccessful in creating teachers who teach differently. The student teaching site has the possibility of bridging the gap between theory and practice because it can provide this link between teaching and the context in which it is used.

If teachers are to teach differently they must be exposed to situations which are different from their own traditional school experiences. According to Wood, Cobb, and Yackle (1990), not only new teachers, but teachers in general, cannot make changes in their knowledge and beliefs until they see something problematic in their own classroom. Educational reform sites that advocate change in educational practices and teaching strategies are believed to hold the best promise for changing the knowledge and belief systems of aspiring teachers. In this study it was my intention to test this belief in a context where reforms are demonstrated and new teachers have the opportunity to see that "something else" works, as well as actively participating in the process of making these new ideas work.

Purpose

The purpose of this study is to examine the influence of an educational reform environment on the development and retention of beliefs and knowledge of student teachers during the practice teaching segment of their teacher preparation program.

According to Bullough, Knowles and Crow (1992) and Yin (1989) case studies are valuable when investigating situations where the researcher has little control in real-life situations. This method enables the researcher to preserve the integrity of the subjects' experiences and meanings as well as encouraging sensitivity to changes within the context of the experience without being narrowly bound to preconceived courses of experimentation.

Methods

Subjects

Two student teachers, placed in a science education reform site for their student teaching experience, agreed to participate in this research study. Both student teachers had entered college immediately upon high school graduation and neither had worked at any other job or career prior to entering the teacher education program. At the time of this study they were in the final semester of a four-year middle grades teacher education program at Western State University (names of all persons, places, and institutions are pseudonyms.)

The Site

The school district serves approximately 18,500 students in an urban environment of 50,000 people. Each of the district schools has a 50% minority population due to a federal mandate to racially integrate. Both schools participating in this study were grade 6-8 middle schools with a student population of approximately 800. They were engaged in a state project to reform science education based on National Science Teachers' Association (NSTA) Scope, Sequence, and Coordination (SS&C) and American Association for the Advancement of Science's (AAAS) Project 2061. Although the curriculum in each classroom is based on the same principles, it has become individualized for each teacher and his/her specific classroom.

Data Sources

Student teachers' conceptions of teaching/learning and subject matter were obtained through interviews. Classroom observations documented by a written observational record and audiotapes were conducted in order to ascertain teacher practices. Later these two sets of data were compared in an effort to determine the degree of consistency between beliefs and practice. I also conducted interviews with cooperating teachers, university supervisors and university methods class instructors at various stages throughout the student teaching experience. A chronological account of data collection is presented below.

Pilot Study.

A pilot case study of one student teacher, Ron, placed in a grade 10-12 high school that had adopted several educational reforms, was a precursor to this research project. Although this pilot project only involved one student teacher, the duration was the entire semester of student teaching and the research methods and data collection followed the ones outlined in the following sections.

Background Information.

As part of a previous case study I came to understand various components of the educational reform, Scope, Sequence, and Coordination (SS&C), from National Science Teachers Association's (NSTA) and The State Project for Reform in Science Education's (SPRSE) literature; classroom observations of project classrooms; and interviews with university SPRSE personnel, pilot teachers and school and district administrators. Other data, such as printed student handbooks, school newsletters, curriculum guides, and standardized student test scores were collected and analyzed to develop a picture of the school site.

Initiation of Study.

Prior to beginning student teaching experience, each subject composed a journal entry describing her personal beliefs about teaching and learning, including a metaphor of how she saw herself as teacher. Each pre-service teacher then diagrammed a content teaching area, listing the major concepts and the interrelationships among them. (Originally I requested that student teachers diagram the content area they would be teaching. When they were unable to perform this task, I asked them to choose the science subject matter area in which they had the most confidence.) The subjects performed this same task with what they perceived were the important elements and concerns about teaching. Immediately following this exercise I conducted an interview discussing and clarifying the journal entries and the two diagrams.

The first five weeks of the student teaching experience included a classroom management course which I observed. Before and after this class I interviewed the instructor to determine his beliefs about teaching, learning and the teaching of science; as well as the goals and objectives of the class.

Throughout the Study.

Three observational periods, spaced at regular intervals and varying from one week to three weeks, were scheduled. (The length of each visit was determined by the schedule of the school and the student teacher.) Classroom observations targeted teacher explanations and demonstrations, the representations used, the assignment of student tasks, and teacher-student interactions.

Between observations I conducted informal interviews with students, cooperating teachers, administrators, and other staff members concerning their impressions of the reform project and the relationship between the project and student teaching. For one school day I shadowed each student teacher in order to obtain a "snap-shot" of a typical school day from her perspective. Besides observing classes I attended meetings, followed the student teacher during "hall duty" and participated in the "lunch room experience."

Throughout the semester student teachers provided classroom materials (tests, quizzes, worksheets, etc.) and copies of their lesson plans. Each student teacher also kept a journal.

Conclusion of the Study.

I conducted a second formal interview of the student teachers during the last week of the field experience, following the focus and structure of the introductory interview.

First, I asked each student teacher to draw two diagrams (science subject matter concepts and teaching and learning concepts) similar to those constructed at the beginning of the study. I asked the student teachers to compare their current views with their responses given during the first interview.

I also conducted final interviews with each cooperating teacher and university supervisor. Copies of written journals and audiotaped journals were provided to me. I also kept a personal journal.

Results

During the formal analysis stage I followed the original theoretical propositions that led to the case study (Yin, 1989), rereading the original research questions and forming a domain and preliminary taxonomic analysis. The domains were then used to construct the descriptive framework of the cases.

In order to determine the depth and breadth of the reform at each site I charted the features of each reform effort, listed differences between features described in the national SS&C literature and the reality of the school site, and charted the student teachers' involvement in the reform at each site. The development of the student teachers' beliefs, and practices during the student teaching experience was determined by matching their practice with their stated beliefs and documenting any discrepancies or changes. I then matched patterns predicted from the conceptual framework, literature review, and pilot study with patterns identified in the case studies.

I expanded the pattern-matching strategy to include explanation-building (Yin, 1989). For example, when I found that the collaboration observed in the pilot study was not present at either research site, I looked for similarities and differences across the sites which could explain the reason for the discrepancy.

I compared the two case studies of this research project with each other, and with the pilot study in order to generate alternate explanations and create a cross-case analysis. In the following sections I endeavor to generate a collage of student teacher beliefs, subject matter knowledge, classroom practices, and the interrelationships of all three. When possible I use the words of the participants in this study and paint a picture of the classroom using vignettes generated by classroom observation. I begin the story with Marilyn, a student teacher placed in a 7th grade science class at Fairview Middle School.

Student Teacher Beliefs

Marilyn

During the pre-student teaching interview Marilyn described her view of the perfect teacher. (She was unable to think of a metaphor.)

> I think you should make your classes interesting. I don't think it should be just textbook-styled. You should bring the students into your class. It should be inviting... and they should not just walk into class and it just be the same thing everyday. It should be fun, not routine.

Marilyn discussed the teaching methods she would use.

> Cooperative learning and forums. Set up forums in the classroom. And set your class up in circles. Talk to the students and make them feel welcome. Make the class atmosphere fun. Put posters up everywhere and make everything enjoyable. When

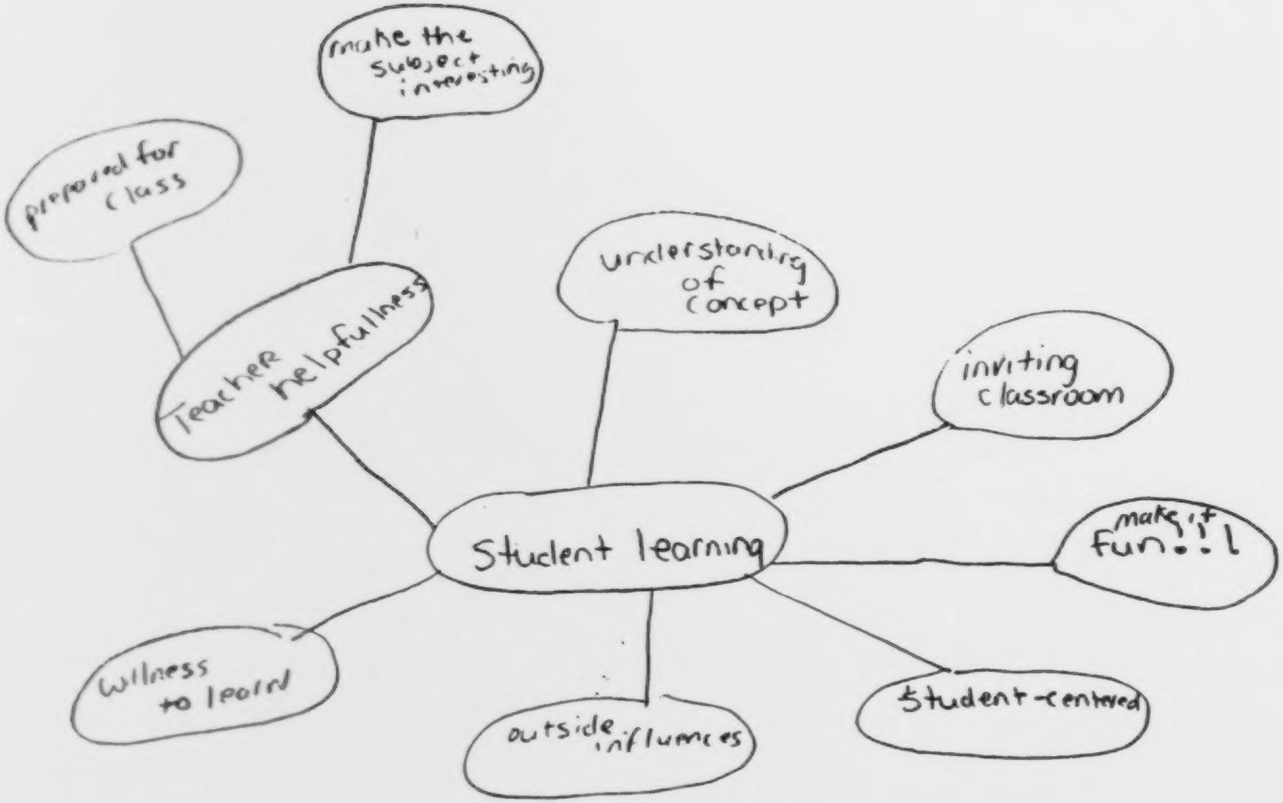
> you teach, don't just stand up in front of the class and lecture. Bring the students in and have them get up in front of the class and lecture. Have them get up there and talk about a subject. Make them welcome and just have fun. Don't make it teacher-oriented but student- oriented.

Marilyn discussed the importance of not overwhelming the students and pacing learning to meet the needs of students. Although she did not use the word, tracking, she said she did not believe in "mixing everybody together." Students should be grouped according to ability level. In conclusion Marilyn drew a diagram representing her view of student learning and the interaction of the factors influencing student learning (Figure 1).

Second visit. Halfway through the student teaching experience Marilyn went home to discuss her problems in student teaching with her father. She was having serious reservations about continuing in the program. Student teaching was nothing like she expected. Her cooperating teacher, Connie, reported that Marilyn was having serious problems with classroom discipline, subject matter knowledge, and lesson planning. Communication problems had developed between Marilyn and Connie. They had stopped talking to each other. Connie reported that Marilyn ignored instructions to improve her teaching and Marilyn felt that Connie was unreasonable in her expectations.

Marilyn decided to return to student teaching in order to graduate, but not to teach. During the next three weeks Marilyn did not teach any classes. Her cooperating teacher and university supervisor relieved her of all teaching responsibilities. She worked independently, researching the subject matter and planning the science classes she was expected to teach later in the semester.

Figure 1. Marilyn's Initial Diagram of Teaching and Learning


make the subject interesting
prepared for class
Teacher helpfullness
understanding of concept
inviting classroom
Student learning
make it Fun!!!
willness to learn
outside influences
Student-centered

After Marilyn resumed her teaching responsibilities, she was no longer concerned about the reform program or the best way to teach; she was only concerned with survival in the classroom. Her frustration was evident in her journal entry the day she returned to teaching.

> Today was a terrible day. The student [sic] were not listening to anything I said today. I felt they could not hear anything that I was saying. I am so upset and it is making me think again about being a teacher. I like to teacher [sic] the material but the major responsible [sic] of the teacher is the discipline.

At the end of the student teaching experience Marilyn supplied a metaphor of a teacher.

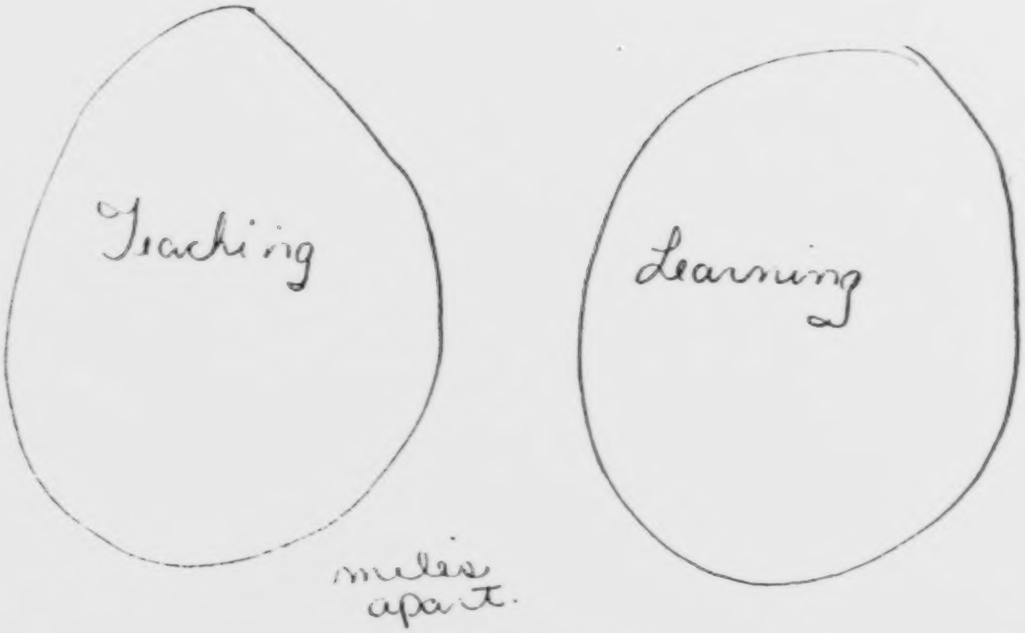
> Yes, a disciplinarian. Basically that's what I believe. There's not much learning going on, just disciplining, asking them to be quiet and calming them down. They come to your classroom and don't know how to behave. I think teaching and learning are miles apart. I mean, you can try to teach but it seems like nothing gets across to them no matter what you do. I don't think that students today want to learn. I feel that they'd rather just sit there and do what they want to do rather than sit there and try to learn anything.

As Marilyn diagrammed her view of teaching and learning, she drew two circles, one for teaching and one for learning, and wrote "miles apart" between them. Under the diagrams she wrote the phrase, "Student [sic] today do not want to learn." (figure 2).

> Later I asked Marilyn about her ideas concerning teaching. I would use less activity. It's pretty well all activity-based now. I'd use less and use a textbook. I'd write on the board what the kids really need to know. I feel that that should be enough.

Teaching & Learning

Figure 2. Marilyn's Final Diagram of Teaching and Learning


Teaching
Learning
miles apart.

Student today do not want To learn.

Then I asked Marilyn, "From your experiences how do you think students learn?"

"Kids don't learn!"

Laura

Both student teachers were engaged in their field experiences during the same semester but Laura, the other student teacher, was placed at Gateway Middle School on the other side of the river. During the first interview Laura described her "ideal" class as the students being actively engaged in activities and experiments because "they remember better when they do it." She wanted to make her class "inviting" and friendly "so that they could come to me with their problems." Laura described a teacher as...

> A doctor or the mother of an animal, always looking out for and watching over the students.

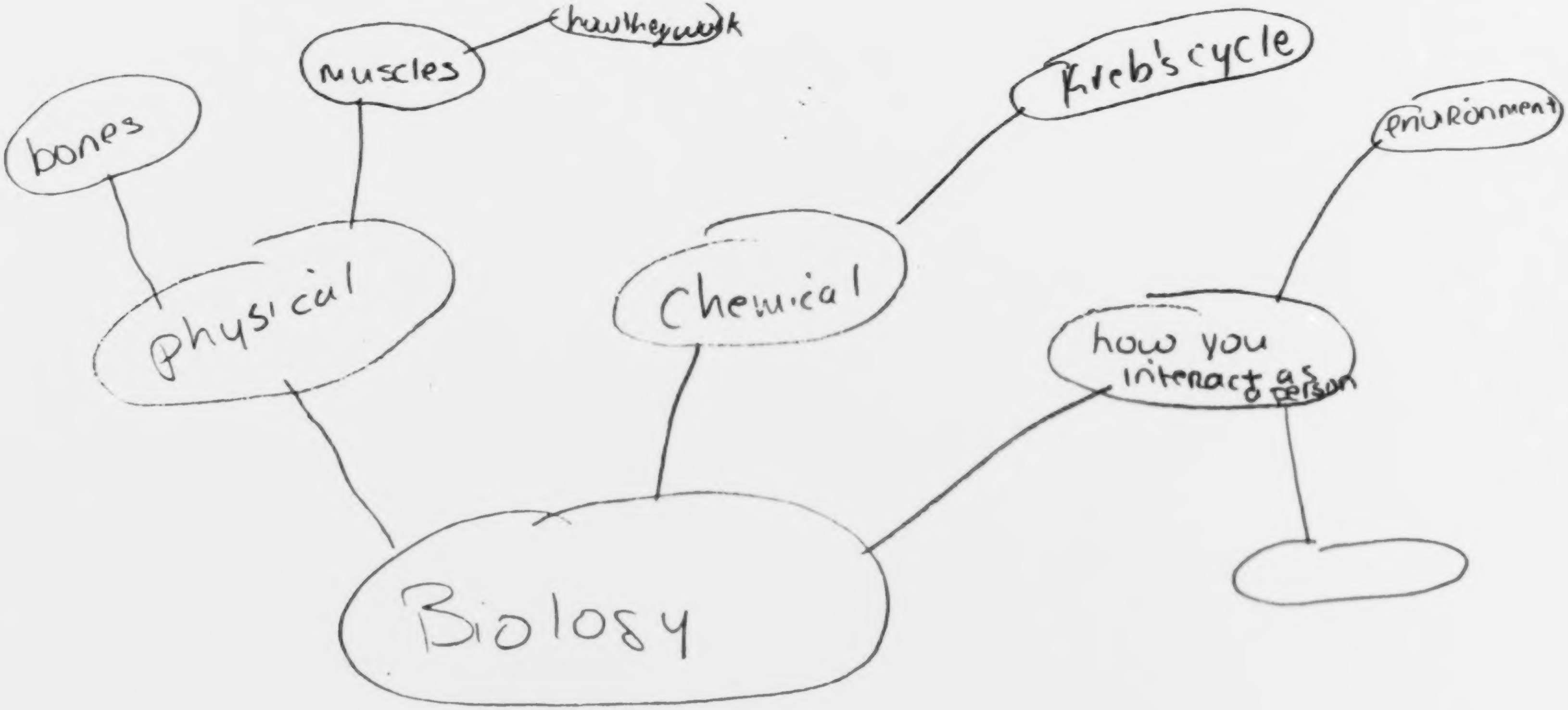
She said that her classes would be neither student-centered nor teacher-centered.

> From what I've seen student-directed classes are a disaster. I would have student input but it would be limited. I would have a class that was in-between. The teacher would be in charge but the students would have some input.

Laura diagrammed her view of teaching and student learning.

(See Figure 5) She drew student learning in the center of the page with lines radiating from it to represent the 11 factors that she believed influenced student learning. Five of these factors involved the students' motivation to learn: new, fun, exciting, interest (connection to everyday life), and desire.

Figure 5. Marilyn's Diagram of Biological Concepts


how they work
muscles
bones
physical
Kreb's cycle
Chemical
envronment
how you interact as a person
Biology

After teaching for two weeks, Laura remarked that she was enjoying student teaching. She had developed good rapport with the students, talking easily with them and them with her. Laura listed her major concern as the lack of a textbook and equipment for doing the science education reform activities. She admitted that she had lost some of her enthusiasm for teaching science and liked teaching mathematics more.

> It's hard to determine if the students got the concepts and also harder to plan. I like math because it's more structured, easier to test and plan.

Like Marilyn, Laura was concerned with discipline problems.

> ...the kids talk a lot and I often have problems getting them back … kids aren't use to cooperative groups so they talk or want to want to work with others in other groups.

Toward the end of the student teaching experience Laura used Project Wild lessons. (She was trained and certified during an earlier experience.) Her Project Wild lessons were more student-centered and she relied less on textbook definitions and notes.

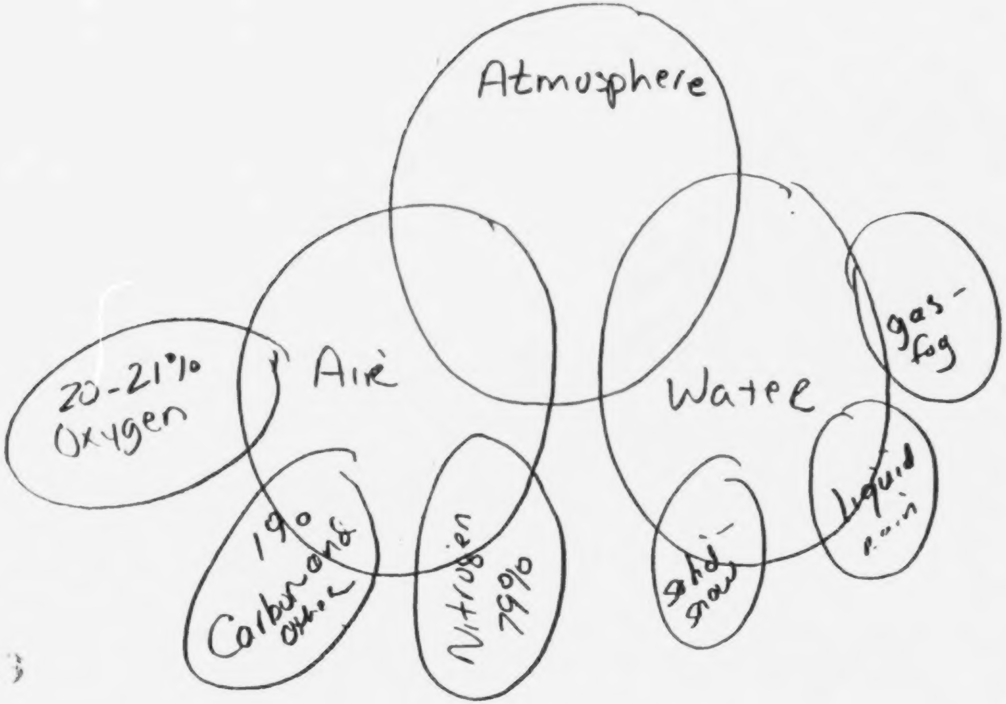
At the conclusion of the student teaching experience Laura gave her same metaphor of a teacher.

> I still agree that a teacher is like a mother or a baby-sitter, especially at this age.

Laura began her diagram of teaching and learning by writing good teaching in the center of the page, circling these words and drawing lines radiating outward from the words "good teaching" to all the ingredients she felt went into "good teaching." (See Figure 6).

Figure 6. Marilyn's Diagram of Weather Concepts

Atmosphere – Troposphere


Atmosphere
20-21% Oxygen
Aire
1% Carbon dioxide
Nitrogen 79%
Watee
gas - fog
liquid rain
solid snow

Laura recalled her experiences during this past semester and described how she thinks students learn.

> Kids learn by doing. If they do an activity or an experiment ... and then being quizzed on it everyday. Drill and practice, that's how I learned.

Keeping this view of how students learned, she described what she did in her classes.

> Well, I don't do it everyday, but as Dr. Shearer said, focus on the review. I'll have them go over what I want them to know at the beginning (of class) like definitions, and also a lot of hands-on activities.

Laura said her view of teaching had changed over the semester. She stated that she did not realize the struggle to keep students' attention and the amount of energy that middle school students seem to possess. Although her original view of teaching was never totally student-centered she moved even closer to a teacher-controlled model.

> There's a lot more to it. I think it would be easier to teach at a higher level. But at this level (6th grade) you have to always be calming them (students) down and getting them to be quiet ... You have to spend a lot of time on class control and discipline.

> She related her views of the science reform project.

> Well, I like some things, some of the topics. But I think the students should have a pamphlet of resources or something they can take home.

She felt the reform required a lot of extra work, such as going to the library and the university for materials. If given a choice she would not use the reform exclusively. She felt that that some of the activities were unrealistic—taking students on field trips or to a pond.

At the end of the final interview Laura shared her plans for the future.

> I think I'll teach for awhile, but I'm not sure. It's a lot of work for little money. Of course that's not why you teach. I'm thinking about going into some area of medicine. I was in that but I left because I didn't like the chemistry. But I was young and didn't want to study. So I'm thinking about going back into it.

Subject Matter Knowledge

Marilyn

At the beginning of the semester Marilyn said she felt the most prepared to teach science of her two concentrations, math and science. Her collegiate subject knowledge preparation in science included the following: two semesters of chemistry; two semesters of biology; and one semester of microbiology. Since she had not studied any physics, I asked Marilyn if she felt comfortable teaching her first science unit, velocity and motion.

> Not comfortable, not really comfortable at all... because Dr. Baker's class was at the same time as the physics class, so I didn't get the physical science class. I'm not strong in that at all so I'm going to have to do a lot of my own research. I'm probably going to have to go back to my professors and ask them for help and advice.

Marilyn could not diagram the subject matter area she would be teaching, so she chose to draw a diagram depicting important concepts in biology and their relationships. (Figure 3).Marilyn discussed her conception of biology as she drew.

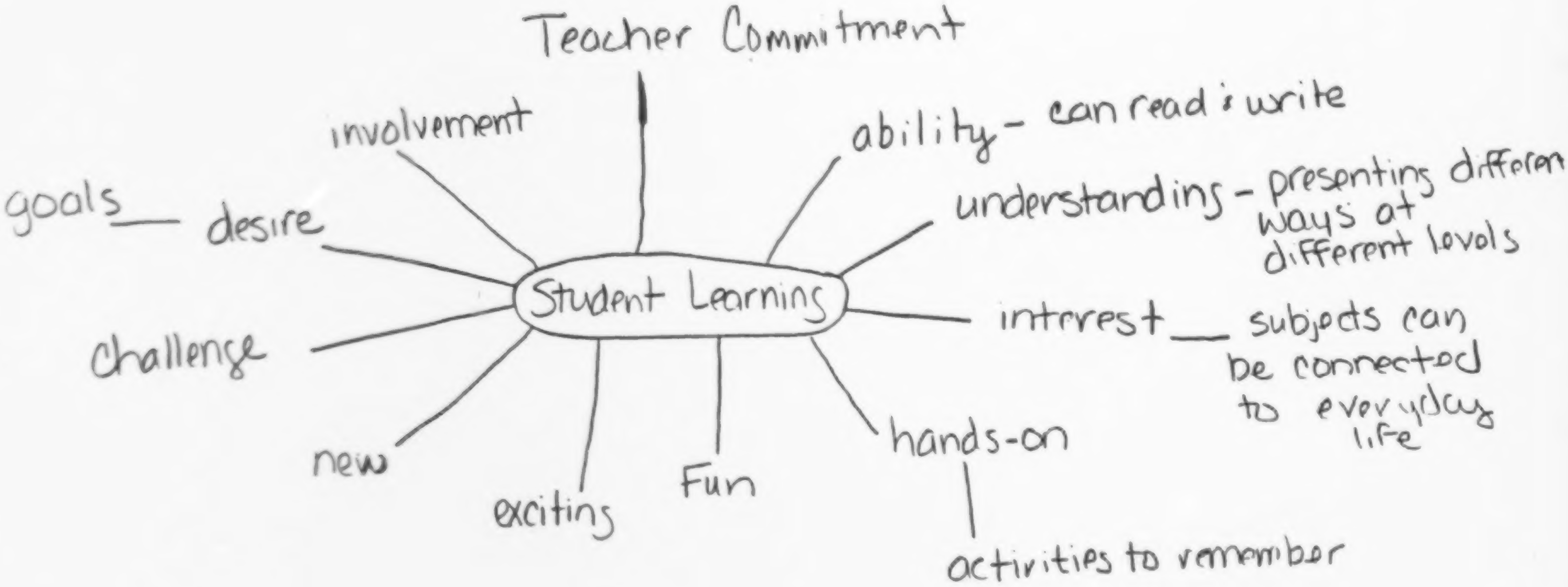
> The different parts of biology would be the physical parts, the chemical parts, when you talk about the Krebs Cycle. And then if it was my lesson plan for the day I would go out and draw the Krebs Cycle. In biology there's three parts to it. There's the physical, the bones and such. Then there's the chemical parts, the Kreb's Cycle. I think there's your physical parts, that's your body. You have your chemical parts, that's inside of you, and then you have your outside. And then how you interact with the environment. It's like biological interaction.

At the end of the first week Marilyn's cooperating teacher expressed frustration. She reported that when students asked Marilyn a question, "she does not know how to respond. She just continues like it wasn't even said."

When Marilyn returned to teaching at the end of April (after being relieved of her teaching responsibilities) she taught the unit on weather. Although she said she felt more comfortable with this unit, I noticed numerous errors in content, such as the incorrect placement of the ionosphere on an overhead transparency. Several times Marilyn could not know explain discrepancies between results students obtained in a laboratory activity and the textbook. On one occasion she asked the class the following question:

> I told Brian that he has air pressure pushing down on him, why doesn't he explode?

Figure 3. Laura's Initial Diagram of Teaching and Learning


Teacher Commitment
involvement
ability - can read & write
goals — desire
understandins - presentins differen ways at different levels
Student Learnins
Challenge
interest — subjects can be connected to everyday life
new
excitins
Fun
hands-on
activities to remember

During four observations students gave wrong answers in class discussions and Marilyn did not correct them. She ignored students when they asked, "What are millibars?" and "How do radio waves effect the ozone layer?"

Misinformation verbalized by Marilyn included the following: high pressure means the density of the air is falling; increasing air pressure indicates low pressure and sunny weather; and she incorrectly described an aneroid barometer.

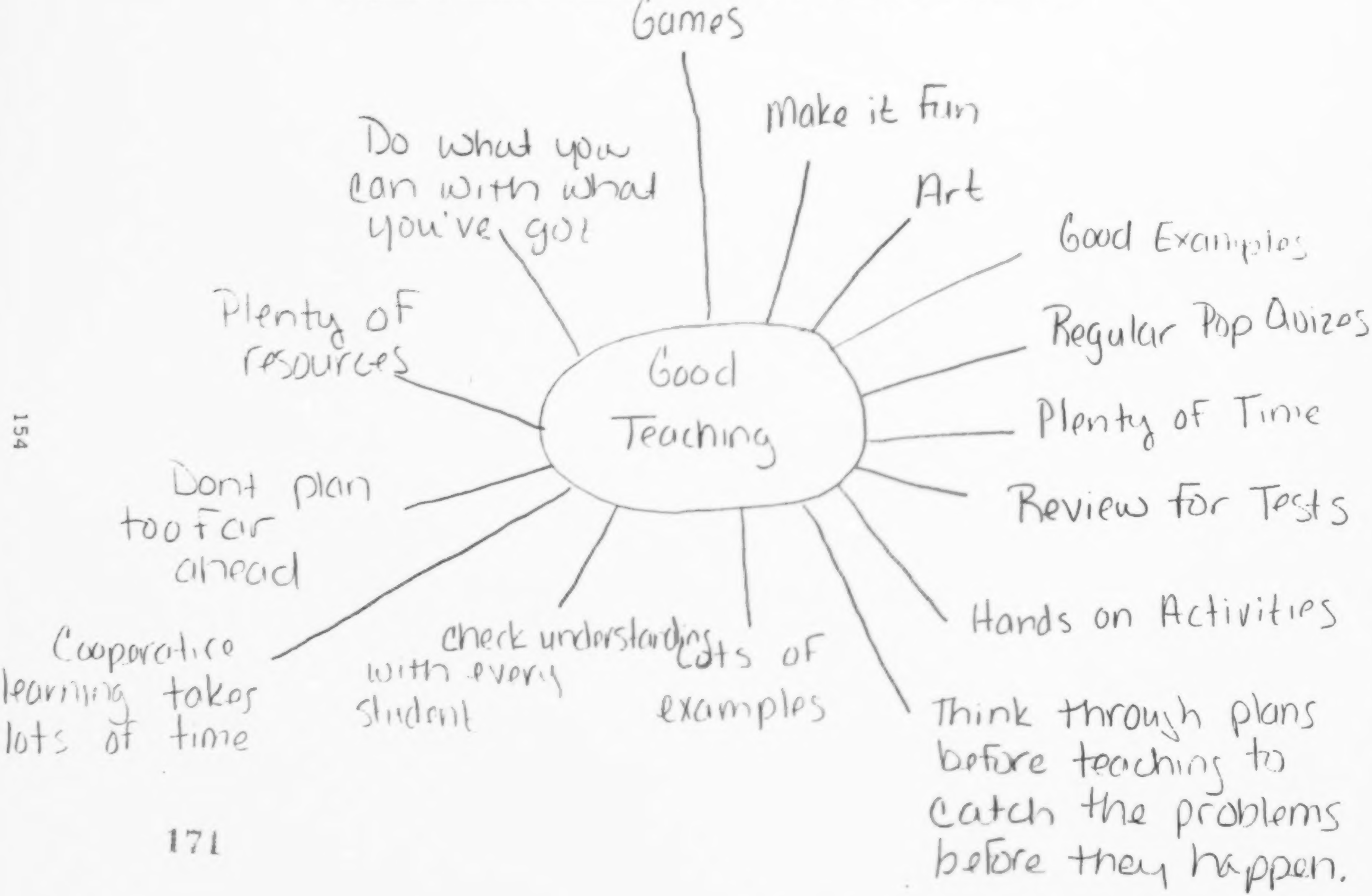
During the final interview Marilyn stated she gained all her knowledge of weather from personal experiences: she did not have any university classes on meteorology or weather. She felt this level of knowledge was sufficient and was unaware of her misconceptions.

Marilyn chose to diagram weather concepts for her final subject matter concept drawing. She said she felt comfortable teaching it and it was "fresh in her mind." (See Figure 4).

As she drew she talked.

> You have the atmosphere. You have two parts of the atmosphere. You have air and water. You have three parts of air. You have oxygen, carbon, and it's 20, 21% depending on the book you look at, and carbon, nitrogen, and...Carbon is like carbon and argon and add up to 1%. And like it's 79% nitrogen, and the atmosphere, it can consist of a lot of things, air. You can take oxygen, carbon, nitrogen. Talk about all the different reactions you can have. Oxygen and how you breathe in oxygen and give off carbon dioxide, and nitrogen also. You can go into how you can have rust on them also; what would happen if you would have more oxygen in the air; how much faster things would rust; how fast things would burn. And then you have water, and

Figure4. Laura's Final Diagram of Teaching and Learning


Good Teaching
Games
Make it Fun
Art
Good Examples
Regular Pop Quizes
Plenty of Time
Review for Tests
Hands on Activities
Think through plans before teaching to catch the problems before they happen.
Lots of examples
check understanding with every student
Cooperative learning takes lots of time
Dont plan too far ahead
Plenty of resources
Do what you can with what you've got

> you have these different types. You have solid, liquid, and gas. And all these are in the atmosphere and this is how you have your weather, the interaction of all these. You have the solid, the clouds which are in the atmosphere and then the troposphere. All these clouds are in the troposphere and how all this interacts together. You have your solid as snow, sleet and then liquid is rain. And then gas forms are fog, and they can see that to begin with. Then you can go into how everything works together.

Marilyn explained that she prepared for class by taking notes from a textbook and writing down questions to ask in class. "I write it down and then have it in front of me when I talk in class. I don't have enough confidence to speak without notes in front of the kids." She said one of her biggest problems was never knowing what questions the kids were going to ask.

As expected with Marilyn's lack of subject matter knowledge, she often verbalized that she did not know how to present concepts to the students and her cooperating teacher commented that she was so preoccupied with facts that she lost sight of how to promote student understanding.

> I've tried to show her that there are many different ways to give information to the students - that was suppose to be the point of today's lesson, guiding the students to find their own information and applying some common sense to it. But Marilyn got so hung up on facts that she lost sight of the major concepts.

By Marilyn's own admission she took facts directly from a book, placed them on an overhead, or had the students read the facts directly from the book. She presented activities in a very structured manner, doing the activity step-by-step as a demonstration prior to the students doing the activity. Marilyn was absorbed by mechanical details of executing the activities and missed the point behind doing the activity or what the students should gain from the exercise.

Laura

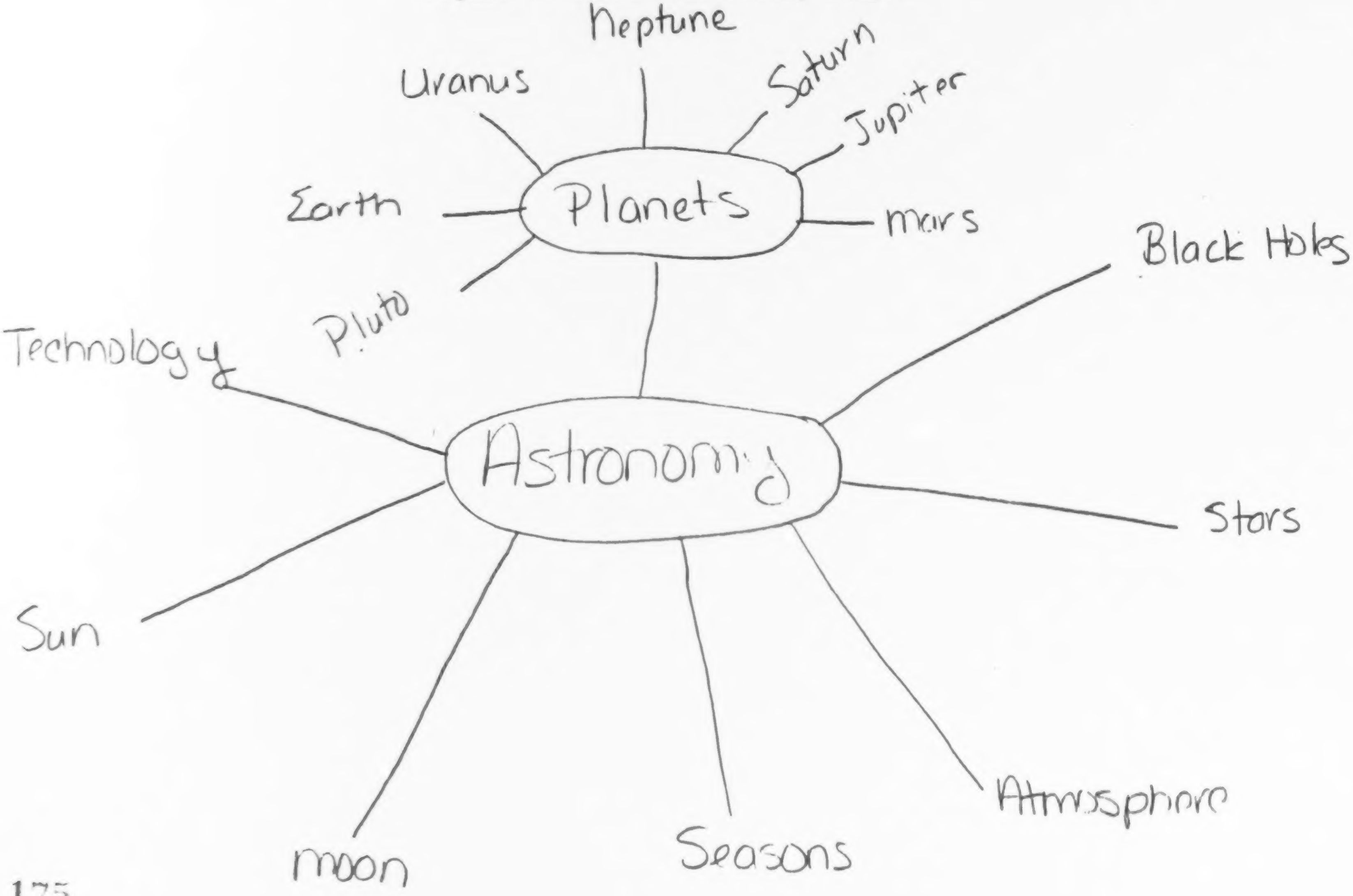
Laura's college science courses included one semester of each of the following: biology, geology, environmental biology, chemistry, and astronomy. She elected not to take physics because she found chemistry difficult and thought physics would be impossible to pass. She described her science courses as primarily lecture courses. Only environmental biology and astronomy contained a laboratory component. She identified the lack of lab courses as one deficiency in her teacher preparation program.

> I think we should have had the labs. I think you look at things differently when you had the lab. We need more labs to do the hands-on. They don't want us to lecture to our kids, so why are all our classes lecture. I think they need special science classes for teachers that are different from the ones everyone else takes.

Although she stated that she felt confident teaching her first science unit, rocks and minerals - she had recently completed a geology course - she elected to draw her subject matter diagram on astronomy during the pre-student teaching interview. (See Figure 7).

She wrote the word planets above astronomy and drew lines radiating out from both planets and astronomy. Relationships between concepts appeared unclear and when I prompted her to explain the connections she could not explain or give reasons why she placed the concepts as she did.

Figure 7. Laura's Astronomy Diagram


Neptune
Uranus
Saturn
Jupiter
Earth
Planets
mars
Black Holes
Pluto
Technology
Astronomy
Stars
Sun
Atmosphere
moon
Seasons

Examples from classroom observations

In Laura's science classes I observed the information she presented to students often superficial and incomplete. For example during a lesson explaining animal adaptation she wrote on the chalk board,

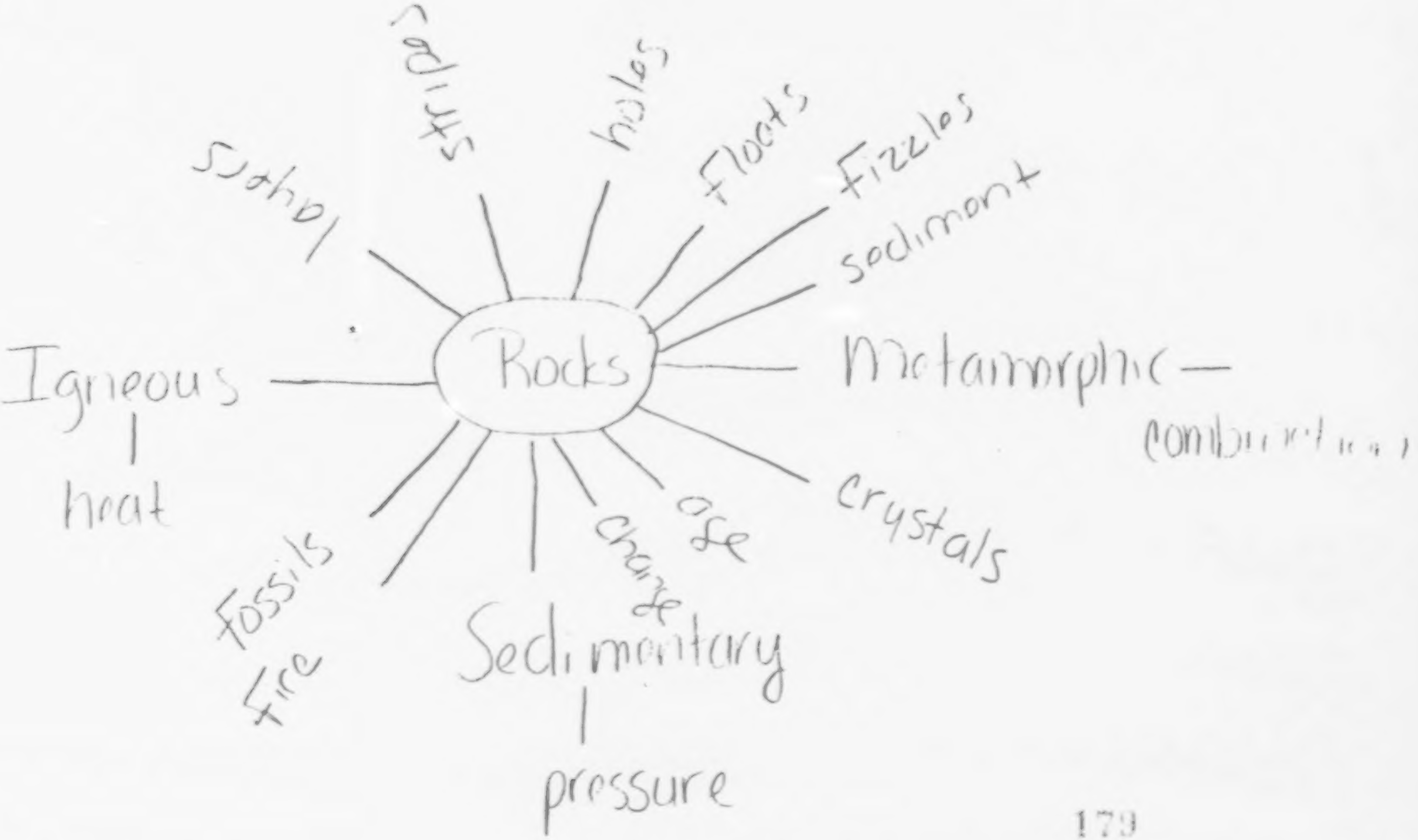
> Polar bears adapt to ice fields and snowy areas. Plants and animals that live in the desert have adapted to heat and little moisture.

She never addressed how the animals adapted to these conditions. During a subsequent activity students researched a variety of environments, identified animals that lived in that environment and the conditions needing special adaptations. Animal structures and behaviors which allowed them to live under such conditions were not identified.

Also, neither the teacher nor the students made any distinction between the river environments in moderate and tropical climates. Students listed beavers, hippopotamuses and flamingos as living together. Laura made no correction nor gave any explanation.

Laura elected to diagram the unit she taught on rocks for her final diagram of subject-matter knowledge. As in her first interview she had a problem organizing and making connections among concepts. (See Figure 8). She also shared her feelings of uncertainty concerning how to teach a concept and what the students were to gain from a lesson.

Figure 8. Laura's Geology Diagram


stripes
holes
layers
Floats
Fizzles
sediment
Rocks
Igneous
heat
Metamorphic —
combustion
crystals
age
change
Fossils
Fire
Sedimentary
pressure

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Practice

The purpose of looking at student teacher practice is to determine if and how student teacher beliefs translate into classroom practice, as well as to determine if there was a mismatch between the beliefs student teachers profess and their actual classroom behaviors and practices. The following vignette of a classroom situation during the final week of student teaching demonstrates how Marilyn's struggle with class management prevented her from executing a SPRSE lesson. The experiment, designed and executed by the students, was the culminating activity for the unit and the end of unit student assessment.

Vignette: Science Class

The student teacher, Marilyn, walks over and flips on the overhead projector light. The question, What will roll down the hill faster a ping pong ball or a basketball? appears on the screen at the front of the room. Marilyn directs the students' attention to the question but is interrupted by a group of students talking loudly. She stops and corrects the students, "If you don't quiet down, I'll make you write questions from the book!" A student in the back of the room responds loud enough to be heard by the rest of the class, "She won't make us do it. She's a whimp!"

Marilyn explains that she wants each group to design and perform an experiment to answer the question presented. They are to collect data and decide on a format to present their results to the class. She explains that this activity will serve as their final assessment on the unit and will take the place of a test. Marilyn directs the students to "get into their groups and start working." Again she threatens to suspend the activity and have the students write if they don't get to work.

While the students are working in groups Marilyn passes out ping pong balls and basketballs. Many of the students begin bouncing and rolling the balls. Two or three groups appear to be working but the majority of the class is either talking about other non-science activities or playing with the balls and other equipment in the room.

Marilyn circulates from group to group, encouraging the students to "get to work" with few results. The students return to their off task behavior as soon as the student teacher moves to the next group.

Although the original intention of the lesson, to present a problem and have the students design and conduct an experiment to solve the problem, matched the philosophy of the science reform project the goals were never met because of class management problems. The class degenerated into pockets of noise and the students were playing with equipment that had been placed on the tables in anticipation of the activity.

Other times during the semester I observed the student teacher attempt activities that demanded student involvement and problem solving, only to have the original activity altered by student behavior or the anticipation of behavioral problems. Reports from the cooperating teacher and university supervisor confirmed my observations. The following situation describes the science class in the preceding vignette several days later.

Vignette: Science Class: Later that Week

Marilyn introduces the lesson by stating, "We're going to do an activity. I'll do the activity first. You watch me and then you'll do it."

At Marilyn's request a student to reads the purpose of the activity from a hand-out, followed by a second student reading off a list of materials. The Marilyn holds up each piece of equipment as the student reads its name. Various students read each step of the procedure with Marilyn performing each action it is read. While this is going on students are throwing paper wads, talking loudly, hitting one another with rulers and generally not paying attention.

After these step-by-step instructions are completed, Marilyn directs the class to do the same lab in their groups. Few groups do the lab. Most of the students use this time to socialize and engage in disruptive behaviors.

The cooperating teacher reported that often Marilyn was unsure of how to respond to classroom behavior, so she simply ignored the disruption, going on with the class as if it were not happening. Classroom discipline problems caused the student teacher to shift from student involved lessons to more teacher directed lessons.

Generally Marilyn's classes followed the pattern: present information by students reading information from a textbook or the overhead; "verbalization" with the students (usually this was a failed attempt because of discipline problems); a student activity (cooperative or individual); and finishing with students copying information - definitions, terminology - from the overhead or a book.

I used Marilyn's lesson plans as the data source in determining her goals for student learning. Because she was attempting to use SPRSE materials—including lesson plans as they were given to her—few of the goals were her own. When I questioned her during interviews concerning student goals she had difficulty articulating any goals beyond getting the students to behave.

Laura's lesson plans and class presentations followed the six point lesson plan: focus and review, statement of objective, teacher input, guided practice, independent practice, and closure-a lesson formula which reportedly was advocated in her methods courses.

Teacher input occupied a large percentage of class time. In about 50% of the classes (data obtained through classroom observations and lesson plans) Laura already had notes on the board when the students entered the room. During class she would read the notes aloud and have the students copy the notes. independent practice consisted of a homework assignment such as, writing a paragraph about rock changes, collecting rock and soil samples, or completing a worksheet.

During closure Laura would either ask a student to summarize the lesson or ask questions about an activity. On a few occasions the students reviewed definitions for closure.

Laura obtained the activities she used from a variety of sources: activities from methods classes, textbooks and lab manuals obtained from the university library, convention materials, and Project Wild (She attended a ten hour training session for this project). But she seldom used the science reform materials. She explained that the school did not have the necessary materials and that many activities were unrealistic (e.g., taking students out of the classroom for outdoor experiences or field trips). Laura expressed her opinion that taking the students out of the classroom would mean a loss of student control.

Test questions usually asked students to recall class notes.

Samples of test questions included the following:

1. List the layers of the soil.
2. List the layers of the atmosphere.
3. Name the gaseous layer that covers the earth and acts like a blanket.

Discussion

The findings of this study document the importance of the environment in which the student teacher learns how to integrate educational theory within their classroom practice. One premise of this study was that student teachers must be exposed to teaching situations which are different from their own traditional school experiences, if they were to teach differently.

The two research sites for this study, along with the site for the pilot study, provided very different environments for the student teaching experience. The pilot study was conducted at a senior (grades 10-12) high school engaged in a large scale school reform. The focus of the pilot study was the Integrated American Studies Core which integrated English, science, and social studies for 10th grade students. This reform was a local effort and was not part of any state or national program. Each teacher was a member of an interdisciplinary team and all team members were actively engaged in the reform.

In contrast the two research sites for this study were middle schools (grades 6-8) involved in a statewide effort to enact a national science reform project. Although each teacher was a member of an interdisciplinary team only the science teachers were participating in the reform. Despite the fact that both schools were enacting the same state science project, the reform looked different at each school. One of the principal differences was that one school, Fairview Middle School, was invited to be a pilot school for the project. (The teachers voted to participate and became curriculum writers for the project). At Gateway Middle School the principal made the decision to be involved in the science reform, and the teachers were given a curriculum other teachers had written.

During the pilot study for this research project I identified several features of the reform environment that were potentially valuable to student teachers: the principal players are open to new ideas and collaborate together to bring about change; the teachers are treated as professionals and are encouraged to develop curriculum, teaching strategies, and assessment instruments for their students; the teachers are encouraged to experiment and receive non-threatening feedback from other "team members"; and a support system (teachers and/or other professionals who can counsel, provide encouragement, and sometimes just listen) exists for the teachers as they experiment with new curriculum and innovative strategies.

Although I found many of these features present at Fairview Middle School, the feeling of openness to new ideas and collaboration among teachers did not extend to the student teacher. The science teachers, especially during the first two years of writing and implementing the reform, were open to new ideas and collaborated together. The university provided a support network—professors and graduate students who made school visits, encouraged the teachers, served as resource people, and transmitted information among the various pilot schools. After the original implementation process was completed the teachers retreated into their individual classrooms, using the reform project science in a manner and to the degree of their choice. There was little communication among the science teachers, especially of different grade levels and with new teachers.

At Gateway the teachers were focused on classroom control issues which made them reluctant to try new strategies which, they felt, could result in management problems. Because Gateway Middle School was not a reform project pilot school, they did not receive the same level of university support.

One advantage of the Rockview field site, which contributed to the development of the student teacher, was Ron's (the student teacher's) acceptance as a full participating member of the team. He was invited to try different teaching and assessment strategies with the classes in a non-threatening atmosphere. Other team members, including his cooperating teacher, did not criticize but made recommendations and suggestions.

The student teachers at both Fairview and Gateway Middle Schools did not have the opportunity to collaborate, engage in team planning, or participate in the inservice associated with the reform. In fact, even though the cooperating teachers were involved in the reform, they encouraged the student teachers to teach in more traditional ways.

Laura's cooperating teacher, Theresa, did not really believe in the reform and Connie felt that Marilyn, her student teacher, was not experienced enough to handle the teaching strategies associated with the reform.

Marilyn's lesson plans consisted only of materials provided by her cooperating teacher or the other seventh grade science teacher. She did not deviate from the pre-selected lessons because she felt that she only had one opportunity to "get it right" when teaching a lesson. In her mind there was no opportunity to experiment. She felt, "you (student teacher) have to teach as your cooperating teacher teaches." Marilyn believed that both her cooperating teacher and university supervisor held her to one preset teaching formula and were critical if she deviated from the expected.

When problems developed Marilyn would not ask for help, and her cooperating teacher and university supervisor had given up on her. The lines of communication among the principal players— student teacher, cooperating teacher, and university supervisor— were completely "shut down". By the middle of the semester Marilyn was only worried about getting through each lesson, and ultimately getting through student teaching—not even getting through successfully—just getting through. Tabachnick and Zeichner (1984) criticize most student teaching experiences because of this fact: the student teachers are mainly concerned with the pragmatic aspects of teaching or "just getting through the lesson" as seen with Laura and Marilyn. The pilot study with Ron demonstrates that although this is true in many cases it does not have to be.

The cooperating teacher was found to be a profound influence on the student teachers in this study. Ron's cooperating teacher, Steve, had previously been a professor in the local university's teacher induction program. Therefore he is well informed in both educational theory and practice. He has extensive experience working with beginning teachers and is willing to devote many hours of his own time to help a new teacher. According to Ron's journal his cooperating teacher worked with him for six or seven hours on a weekend, planning for the following week. When problems arose he helped Ron work through the difficulties, giving him suggestions and support, instead of encouraging the abandonment of new teaching strategies.

Although the other two cooperating teachers had excellent reputations within their own buildings, neither one had Steve's degree of experience working with student teachers. They also expressed feelings that they were overworked and just did not have the time needed to do everything: teach; write and collaborate on the reform curriculum; and attend meetings and workshops required by the school. Consequently if the student teacher needed extra assistance the time just was not there for her.

Connie and Theresa communicated their beliefs to the student teachers in their charge and their practice served as a model of how to teach. They focused on the mechanics of the program and expressed the view that the reform was difficult to teach. They never referred to the underlying philosophy of the project or how working with the program could help the student teachers promote learning in their students.

Unlike Marilyn, Laura had a good working relationship with her cooperating teacher. At the beginning of the experience Laura attempted to incorporate some aspects of the reform into her lessons but her cooperating teacher discouraged the use of the reform in many subtle ways. For example when Laura gave an open-ended test on which many students received low grades, Theresa (the cooperating teacher) encouraged her to give an objective test. When discipline problems arose Theresa suggested having the students read and answer questions in a textbook. Gradually Laura assimilated her cooperating teacher's view of the science reform program and came to believe in the same teacher-centered model as her cooperating teacher.

This study found, that at both Fairview and Gateway, the student teachers' beliefs about teaching and learning were overshadowed by problems with classroom management and discipline, as well as limited subject-matter and pedagogical content knowledge. Marilyn never really got at "how to teach" or "how students learn" because she was never in control of the class and Laura was afraid to "let the kids go."

Both Marilyn and Laura attributed the failure of the student teaching experience to an unrealistic view of teaching and of students from their university experiences, as well as, their own early school experiences. Often Marilyn talked about how she remembered herself as a middle school student and her dismay that her own students did not behave in the same manner. They also stated that university education courses stressed making classes fun and interesting, but did not make them aware that many students would not be interested in what they had to teach.

Marilyn recognized her lack of subject matter knowledge as a liability during the first half of the semester but stated that her knowledge of weather was sufficient. Laura felt that a lack of laboratory experiences in her teacher preparation left her unprepared to teach SPRSE Science. Although, throughout the semester both student teachers verbalized their struggle with "how to teach," they failed to view their lack of subject matter knowledge as contributing to this problem.

The student teachers began their experiences with the reform project with less preparation in the major elements of the reform than the experienced teachers who originally implemented the project. The science teachers at Fairview Middle School had the benefit of a two week summer institute in which they were introduced to the principles of the reform, gained some experience with the associated teaching strategies, and became involved with collaboratively writing reform curricula. The student teachers did not have an opportunity to attend the summer institute nor did they receive the university support accorded the classroom teachers when they began implementing the project.

Although Ron exhibited some of the same inadequacies as Marilyn and Laura, he was able to overcome problems and develop into a competent and caring teacher because he was placed in an atmosphere that encouraged the student teacher to experiment, engaged the student teacher as a full participant in the schooling process, and provided a support system when he needed it.

Conclusion

Previous to student teaching Marilyn and Laura, the student teachers in this study, expressed very idealistic views of teaching and learning. But many of their ideas changed when faced with keeping the students' attention and coping with classroom problems on a daily basis. Both student teachers reverted to a teacher-centered model of instruction and viewing science as a body of facts to be presented to their students.

Student discipline issues at the two sites were a major factor which dispelled many of the student teachers' beliefs concerning increased student involvement in the classroom and created an issue that they could not resolve. They adopted the belief of their cooperating teachers that the choice was either class control or the reform project.

The most significant determining factors of how the student teachers taught were their knowledge of the subject area and concerns of classroom management. Their beliefs about teaching and learning had shifted from a focus on how students learn (prior to student teaching) to how teachers should teach (at the end of the experience). During informal discussions at the end of the experience, Laura expressed her belief that students need drill and practice—because that was how she learned—and the value of a quiet, orderly classroom. Marilyn was less articulate concerning her beliefs about teaching and learning at the end of the experience. She expressed her frustration with the students and talked about her efforts to regain control of the classroom. Even when prompted she refused to discuss how students learn. Both student teachers' practice at the end of the experience reflected this shift toward teacher-centered instruction.

Although reform programs were operating at both schools, the student teaching situations were not different from traditional classroom situations. The student teachers were not actively involved with any of the changes advocated by the reform, and no opportunities were provided for reflection.

In this study the reform project curriculum was expected to be a driving force which would influence the school and the students. In reality the school (especially the teachers) and the students had a profound effect on the manifestation of the reform project in each classroom—including the student teachers' classrooms. The cooperating teachers were a powerful influence during the field experience. Their beliefs were communicated to the student teachers in their charge and their practice served as a model of how to teach. Both cooperating teachers focused on the mechanics of the program, and student discipline.

The experience with the reform project had the effect of "turning these student teachers off" to educational reform efforts and teaching in general.

Implications for Teacher Educators

With the current movement for educational reform in this country there exists a need for teachers who "teach differently." The problem is how to produce teachers who have the beliefs, knowledge and practice which are consistent with today's reform efforts. One thought is to expose pre-service teachers to these ideas early in their teacher preparation programs and have them engage in practice teaching in schools participating in the reforms.

Recommendations

1. Communication. From the results of the pilot study and the two case studies of this research project the single most critical issue in the field experience is simply people talking to other people. Linn (1992) recommended that collaboration and

communications include all individuals involved in teacher education. Not only should people talk to one another but the level of communication is also important. Instead of the student teacher being treated as a student and told what to do, as in the case of the two student teachers (Laura and Marilyn), the student teachers should be included as part of the team (student teacher, cooperating teacher, university supervisor and other teacher involved in teaching the same students).

2. Selection of schools for field experiences. In order to derive maximum benefit from such a teacher preparation program the schools must be carefully selected to be certain that a true reform environment exists. Cooperating teachers and university supervisors must be carefully screened to provide support personnel for student teachers as they try to implement the reform. Cooperating teachers and university supervisors who do not "buy in" to the reform can send conflicting messages which can undermine the student teachers' progress. Such personnel also need to be trained to deal with student teachers' problems and have time in their schedules to conference and work with the student teachers.

3. A support structure for student teachers. Student teachers also need a support structure to help make the transition from traditional teaching strategies to the student-centered classrooms advocated by many educational reforms. The student teachers need to have a voice, put forth their ideas with other teachers commenting and making suggestions in a non-threatening manner. The student teacher should have an opportunity to try their ideas with other team members providing support. Support in this situation means giving praise when an action yields good results,

making suggestions for improvement, and providing encouragement when something goes wrong.

4. Student teacher subject matter preparation. Student teachers need to be adequately prepared for the subject matter they will be teaching. Schools of education need to look carefully at their particular subject matter requirements, analyzing the number of courses required and the content of these courses, and making changes if their requirements seem insufficient. Student teachers who must struggle with content have an extra burden as they endeavor to manage a classroom and deal with the many facets of student instruction and learning.
5. Student Teacher pedagogical preparation. Aspiring teachers have spent a minimum of 12 years in the educational system acquiring a view of what they believe should be happening in the classroom. It is a challenge to teacher educators to dispel many misconceptions and replace them with a view of educational practice grounded in research.
6. Integration and consistency of program. Today there are a number of different teacher education programs, each with its own underlying philosophy, values and benefits. In order for any teacher education program to be effective, the total teacher education program—classes, practicums, student teaching and other experiences—must be truly integrated, give aspiring teachers practical experience throughout the program, and be internally consistent. Conflicting messages can undermine an otherwise, good program and yield undesirable results.

Learning to teach is a complex process. Many factors influence the future teacher. Although some are out of the control of teacher educators, the field experience can be carefully constructed to reinforce beliefs about teaching and learning advocated in pre-service education courses. The alternative is for the field experience to undo any progress made in changing the attitudes of future teachers.

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Science Experiences and Attitudes of Elementary Education Majors as they Experience an Alternative Content Biology course: A Multiple Case Study and Substantive Theory

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The purpose or objective of the study

Science literacy/preparation for students at all levels of learning has been a topic of great concern in the education community for the past decade (AAAS, Project 2061 & Benchmarks). The professional literature clearly notes a lack of science preparation and literacy for elementary teachers being prepared by universities. (NRC, 1996; Fort, 1993; Tobias, 1992 & 1990). Researchers suggest that the problem of science literacy, stemming from early years in schooling, is perpetuated in the current structure of the undergraduate introductory level science courses. They propose that negative or passive attitudes are rekindled and solidified and are subsequently passed on to the next generation of learners. The National Research Council's (NRC) (1990) identified problems and needs are explained in *Fulfilling the Promise: Biology Education in the Nation's Schools*. They state that:

> Teachers of science in elementary school must be far better prepared than are most at present. To disguise their anxieties about science, most elementary school science teachers have hidden behind textbook-centered lessons that stress vocabulary and memorization of facts. Given the minimal amount of science instruction taken in college by most elementary -school teachers, that attitude is understandable. But the situation must change to achieve quality science instruction in the elementary schools. . . (p.16).

Preservice elementary teachers' science preparation is described as inadequate, both in content and methodology of instruction (NRC, 1996, NRC, 1990; Tobias 1992). These studies attribute the lack of preparation to: 1) The structure of traditional introductory level content science and methods courses and 2) The prevailing attitude among most elementary education majors that science and math are difficult and uninteresting subjects. This study proposes that both preparation issues are interrelated and that the problem may be addressed by developing collaborative content science courses for preservice teachers between science departments and teacher colleges which integrate the methodologies and pedagogies currently advocated by national reform efforts in conjunction with the teaching and learning of content science.

The purpose of this study was to explore science experiences and attitudes in a select group of preservice elementary education majors enrolled in an experimental introductory level content biology course offered through the department of life sciences, but jointly taught with instructors from both the Department of Life Sciences and the Teahcers College. Preliminary significant quantitative measures led to a qualitative case study methodology which produced a holistic picture of how a preservice elementary teacher experiences this course. Multiple case comparisons have led to the generation of a substantive theory of the progressional aspects or hurdles that elementary preservice teachers encounter, overcome, and achieve as they learn science in this alternative environment.

Conceptual framework

In the fall semester of 1993 a new undergraduate content biology course for elementary education majors was designed; Biological Sciences 295 (Bio 295).

Biology 295 (Hands-on Biology for Elementary Education Majors) is a course for elementary education majors designed to teach simultaneously biological concepts and pedagogy through the scientific process. This course is based upon the science literacy standards advocated by the National Research Council in the recently released *National Science Education Standards* (1996 and preceding draft editions), the American Association for Advancement in Science (AAAS) in *Project 2061* (AAAS, 1989), *Benchmarks* (AAAS, 1994), National Science

Teachers Association's (NSTA) *Scope, Sequence & Coordination of Secondary School Science: Vol. I - Content Core: A Guideline for Curriculum Designers* and Vol II - *Relevant Research* (1992), and Nebraska Department of Education's *Math and Science Frameworks* (1994). Also considered are the goals of the nation and the state as covered in Project 2000.

The philosophy of the course is rooted in constructivism, thus emphasizing individual students' background, culture, philosophies, and needs (Tobin, 1993; Cobern, 1989; Von Glasersfeld, 1989). The curriculum provides students with a knowledge base of biological concepts and integrates pedagogy traditionally taught in separate education classes.

The knowledge base, as explored in the course, allows prospective teachers to do hands-on activities and to use discovery/inquiry types of instructional techniques which require a profound understanding of biological content. The curriculum aims to encourage preservice elementary education majors to integrate biological concepts more substantively into their teaching curriculum.

The curriculum also provides for modes of alternative assessment which require students to demonstrate their ability and knowledge through performance related tasks. The course is designed to empower preservice elementary education majors to become agents of change, so that they in turn may empower their students to guide their own learning through the scientific process.

Since the Spring term 1994 quantitative data have been collected on both content biology and attitude surveys. Content biology was measured by using a pre / post test design on the National Association of Biology Teachers (NABT) Biology Content Exam. In a previous study (Bruning & Glider; unpublished), thirty questions had been selected from the NABT exam and administered to general Biology 101 courses at UNL. This instrument was administered each semester to the Biology 295 students. Results from a pre / post two- tailed t test analysis show significant alpha values (<.05) for each semester demonstrating that studnets learned significant biology content during the semester. Results from the two sections of the Fall semester 1995 are shown in (Appendix A: Table 1). Other semesters are not included in the table but had similar significance of <.001.

The Science Attitudes survey (Bruning, unpublished) is a survey which explores seven areas related to overall confidence and attitude. Areas examined are: A) Confidence in learning science as a student; B) Utility of science; C) Affect of science; D) Gender and ability to learn science; E) Constructivist learning and teaching in science; F) Confidence in teaching content science in the classroom and; G) Confidence in teaching science and sharing it in professional circles. The Science Attitudes survey has been administered each semester to the Biology 295 students. Results from a pre / post two tailed t-test analysis show significant alpha values for each semester in each category. A comprehensive analysis of all the students thus far also showed significant alpha values for each component of the test. (Appendix A, Table 2)

The preliminary quantitative findings proved encouraging and led to further questions about the course. Many studies conclude with the development, evaluation, significant quantitative findings, and resulting publicity. However, making a difference is only the beginning to understanding how and why these significant changes were brought about.

Biology 295 is an unique bounded system and all of the above situations and recognitions provide a rationale to study the course qualitatively. Specifically, studying the experiences and attitudinal progression of preservice elementary education majors over the duration of the course could provide valuable information which may lead to the development of theories on how alternative science courses help students overcome barriers to learning and teaching science.

This also addresses the national concern of science literacy for students on all levels and their respective teachers.

Methodology:

Having a quantitative basis to show that a significant event has taken place, qualitative analyses were required to explain the how and why changes occurred as a result of experiencing Biology 295. Therefore, the research for this study follows the qualitative paradigm and attempts to explain the significant quantitative findings while concurrently distilling patterns that emerge from the participants experiences thus leading to the generation of a substantive theory of learning science in an alternative setting.

Merriam (1988) defined qualitative research and emphasized the need to explore subjective phenomenon: "(Q)ualitative research assumes that there are multiple realities - that the world is not an objective thing out there but a function of personal interaction and perception. It is a highly subjective phenomenon in need of interpreting rather than measuring" (p.17).

Having multiple data sources, a context or bounded system, and a phenomenon to study led to a case study design. A Case study is universally defined as, "(A) detailed examination of one setting, or a single subject, a single depository of documents, or one particular event" (Bogdan & Biklen, 1992, p.62). Merriam (1988) further clarified a case study as "an examination of a specific phenomenon such as a program, an event, a person, a process, an institution, or a social group"(p.9). Case studies require that the subject or phenomenon being studied qualify as a bounded system. Merriam (1988) explains, "The bounded system, or case, might be selected because it is an instance of some concern, issue or hypothesis" (p.10). Adelman, Jenkins and Kemmis (1983), simplify the explanation by stating, "The most straight forward examples of 'bounded systems' are those in which the boundaries have a common sense obviousness, e.g. an individual teacher, a single school, or perhaps an innovatory programme" (p.3).

Additional exploration of case study designs revealed explanations of multiple case studies. Merriam (1988) explained that "the case study focuses on a single unit within there may be several examples, events, or situations (which) can be exemplified by numerous case studies" (p.46). Yin (1984) proposed that multi case studies try to "build a general explanation that fits each of the individual cases, even though the cases will vary in their details." (p.108). Miles & Huberman (1984) suggested that "by comparing sites or cases, one can establish the range of generality of a finding or explanation, and at the same time, pin down the conditions under which that finding will occur." (p.151).

Further study of Merriam (1988), Bogdan & Biklen (1992), and Denzin & Lincoln (1994), led to the realization that case studies often lend themselves to developing theory. Merriam (1988) explained that, "A qualitative inductive multi case study seeks to build abstractions across cases" (p.154). After clarifying the account of several case studies within the same context or bounded system, Merriam (1988) elaborated, "Anchored in real-life situations, the case study results in a rich and holistic account of the phenomenon. . . . case studies play an important role in advancing a field's knowledge base" (p.32) and that "qualitative case study usually builds theory" (p.57). Stake (1994), suggested that a "Case study can usually be seen as a small step toward grand generalization" (p.238). Finally, Merriam (1988) stated that it is appropriate inductively to discover theory from case study research when there is no theory present which explains the phenomenon. She stated:

> The case study has been widely used, however, in the service of constructing theory. It becomes necessary to build theory when there is none available to

> explain a particular phenomenon or when existing theory does not provide an adequate or appropriate explanation. Eckestein (1975, p.104) calls theory building case studies "heuristic" because they "aim to find out." Case studies that are undertaken to build theory use an inductive rather than deductive mode of thinking about the problem and analyzing the data. These studies, which have as their goal discovery of theory rather than verification, partake of the qualitative paradigm. . . . (p.59).

The research within case study methodology is consistent in emphasizing purposeful selection when selecting individuals as case studies in a bounded system. Merriam (1988) defined and rationalized at the same time purposeful selection:

> (P)robabalistic sampling is not necessary or even justifiable in qualitative research. Anthropologists, for example, have long maintained that nonprobability sampling methods "are logical . . . ." (Honigmann, 1982, p.84). Thus the most appropriate sampling strategy is nonprobablistic - the common form of which is called purposive (Chein, 1981) or purposeful (Patton, 1980). Purposive sampling is based on the assumption that one wants to discover, understand, gain insight; therefore one needs to select a sample from which one can learn the most (pp. 47-48).

Utilizing the methodology of purposeful selection, six preservice elementary education majors [here after referred to as students] were self selected from the Spring 1995 Biology 295 class. The criteria for selection required students with different backgrounds in and understandings of science. Based upon the works of Tobias (1990) and Fort (1993) two students were selected from the First Tier (Tobias) or as Fort suggests, Science Smart. These students possessed a strong science content knowledge and had positive experience with the subject matter. Two students were selected from the Second Tier (Tobias) or as Fort suggests, Science Savvy. These students possessed the ability and confidence to learn science, but had little experience with the content. And, two students were selected from the Third Tier or majority (Tobias) or as Fort suggests, Science Shy. These students possessed ability to learn science, but had attitudes reflecting little or no confidence in learning science as a result of no experience with science or bad experiences previously encountered while learning science.

Using purposeful selection of six participants enabled a multi case study design. Thick and rich descriptions were developed of each participant and their experiences and progression in attitude, confidence and philosophy as they experienced Biology 295. By using cross case analysis to look for common strands and themes, a substantive theory was generated which explores the barriers and hurdles that preservice elementary education majors encounter and overcome in the progression of learning science in this alternative learning environment. This theory was based upon their experiences and attitudes resulting from participation in Biology 295.

The cross case analysis and the generation of the substantive theory were reviewed by an outside reviewer. The outside reviewer read each of the cases and then verified the cross case analysis with accompanying substantive theory as an accurate deduction from the data. Denzin & Lincoln (1994) state that an outside reviewer is an excellent way of keeping the research and theory in the proper context and thereby limiting researcher bias. Therefore, the results, both by individual cases and cross case comparison generate a fair interpretation and theory based upon the attitudes and experiences of these students as they experienced Biology 295.

Nature of the Data

Major data sources for this study included transcripts from pre and post interviews with each participant, journals that each preservice elementary education major kept as a student involved with the Biology 295 course, and video taped segments of the different class sessions.

The interviews with each of the participants were conducted at the beginning of the course and at the end of the course. The final interview allowed the participants to share any further insight that they had relating to experiences and attitudes as a result of being in the course. The interviews were conducted in such a way that the participants felt comfortable to "talk freely about their points of view" (Bogdan & Biklen, p.97).

Posner (1993) came up with a logical formula by which the journaling assignments were based upon: (E + R = PG) "experience plus reflection equals personal growth." As part of the class stipulations, each student was required to keep a reflective journal of the labs, activities, and events of the course in a two way dialogue format. Topics to reflect upon included specific lab activities and related scientific content, relating content to real life experiences, pedagogical strategies modeled or conveyed in class, classroom connections (projecting the usefulness of the content and course to their future classrooms), and their thoughts and feelings that they discovered as they participated in class. All of these journaling experiences were designed to further the students' understanding and learning as a part of their personal growth. Fulwiler (1980) summarized the importance of written documents as the "text content provides a window of understanding about how effectively people observe events, speculate, revise thinking, and reach conclusions."

During the entire semester each lab was video taped. Approximately sixty hours of video tape were accumulated from labs and corresponding activities. The video taping was conducted as a record of the labs and provided a visual component to the written responses that the participants made in their journals

With the above data sources and participant observation records kept by the researcher, massive amounts of rich descriptive data were obtained. Using the qualitative methodology as described above and following the advice of Bogdan & Biklen (1992) that "As you read through your data, certain words, phrases, patterns of behavior, subjects' ways of thinking, and events repeat and stand out" (p.166), the thick and rich descriptions which were developed with each participant and their experiences led to the themes developed by each individual case.

Further analysis incorporated Miles & Huberman (1994) suggested strategies for cross-case analysis. "A conceptual framework oversees the first case study, then successive cases are examined to see whether the new pattern matches the one found earlier" (p.436). Merriam (1988), suggested, "using an 'unordered meta-matrix' - a large chart organized by variables of interest to the researchers that contains bits of narrative such as key phrases, quotes, or other illustrations of the category . . . by doing this one can advance to higher levels of analysis." (p.155).

The higher levels of analysis led to a substantive theory, "a theory restricted to a particular setting, group, time, population, or problem" (Merriam, 1988. p.57), which was based upon the multiple data sources and cross case comparisons.

Findings and Results: Cross Case Analysis and Substantive Theory

Science education and science instruction in the elementary school has been a topic of research for quite some time. In 1978 Weiss found that only 28% of elementary teachers felt qualified to teach science and that on the average 90 minutes per day were spent on reading instruction versus an average of 17 minutes on science instruction. These results have been corroborated by Stefanich and Kelsey (1989) who found that less time is spent on science instruction in elementary schools than any other subject. Of the time spent on science instruction, an earlier study found that 90% of the teachers relied on textbooks for about 90% of their science instruction (Stake and Easley, 1978). Yager and Lutz (1994) found similar results and further explained that science instruction was comprised of students listening to lectures, reading from textbooks, and memorizing, repeating and confirming scientific facts. More importantly, a study done by Roychoudhury, Tippins, & Scantlebury (1995) found that science instruction was generally not connected to students' prior knowledge nor was it relevant to students' everyday lives.

Numerous studies have shown over time that the majority of preservice elementary education majors have negative attitudes toward science (Shrigley, 1974; Morrisey, 1981; Westerback, 1982; Feistritzer & Boyer, 1983; Pedersen & McCurdy, 1992). Of considerable concern is that teachers with negative attitudes toward science can, through their own actions, pass this attitude on to students in their classes (Stolberg, 1969). Ramey-Gassert & Schroyer (1992) have summarized numerous studies concluding that elementary teachers poor self-efficacy has resulted in a science anxiety and that poor attitudes toward science result in an unwillingness or hesitancy to spend any time teaching science. Lucas & Dooley (1982) inferred that poor attitudes toward science can be traced back to the individual's own experiences at school. This assumption was recently validated in a study where autobiographies of 56 preservice elementary teachers were analyzed. The study concluded that "the dominion of text-based science education in the schooling of the preservice teachers and its negative association with experiences in science" was the leading cause of poor attitudes among the participants in the study (Talsma, 1996).

As a result of such research regarding what is and what is not being taught in the schools and more specifically in the elementary classrooms, it is no wonder that the recent reform efforts are underway. The question now becomes whether the reform movements are having any impact on the way science instruction occurs in the content areas, in the teacher preparation programs, and in the public schools.

Science is a process of understanding and exploring the world in which we live. The recently released National Science Education Standards (NRC, 1996) advocate that "Learning science is something that students do, not something that is done to them" (p. 20). The standards also state that "since science content increases and changes, a teacher's understanding in science must keep pace" (p.57). The National Standards go even further to suggest how teachers and prospective teachers should learn and keep pace with science: "Prospective and practicing teachers must take science courses in which they learn science through inquiry, having the same opportunities as their students will have to develop understanding" (p.60).

The standards (NRC, 1996) employ science content as only one part of several facets of science instruction. The standards also equally encourage the process of doing science along with history, philosophy, technology, connections of unifying themes in science, and a personal and social perspective in science with the three basic content areas of life, physical and earth science.

Biology 295, the focus of this research, has provided an experience for prospective teachers which allows them to learn science through situations and activities that are similar to the situations that elementary students will have in order to develop scientific understanding of both the content and process of science. The study conducted for this research has affirmed the findings of past researchers. Furthermore, this study has identified, through thorough analysis of the experiences of the six participants, some striking similarities regarding the hurdles and levels of learning that participants experienced and overcame as they participated in Biology 295.

Each participant came into the course with different backgrounds and experiences in growing up and in learning science. The in-depth case studies reveal similarities and differences in the variety of learning situations of each of the participants throughout the Biology 295 course (Appendix A, Table 3). Each of the participants had learned biology and had kept a good record in their journal of the concepts. Each of the participants made sense of the "new knowledge" through their prior experiences, whether it was growing up on a farm or relating it to activities and experiences encountered in formal and informal science learning situations. Each student had a philosophical progression from which they began with an idea of how science could be taught and learned in their future classroom to a mature vision and plan of how they would teach science in their future classroom. However, probably the most significant similarity surfaced when all six cases were compared and the experiences thoroughly analyzed.

Each of the participants went through five progressional stages as they experienced Biology 295. Upon further analysis, and based upon Merriam's (1988) recommendation that case studies should lead to the generation of a theory, the following substantive theory holds for the six participants studied in depth and is thought to hold for the majority of students who experience Biology 295.

The substantive theory suggested here states that preservice elementary education majors encounter five hurdles, or stages, as they experience Biology 295: 1) Reservations and hesitations or the anxiety stage, 2) Awareness / enjoyment stage, 3) Intrinsic shift, 4) Rapid building of self confidence and self efficacy, and 5) Empowerment. A holistic picture of the reflections encountered in each stage of the theory is depicted in Table 4 in Appendix A. (The dissertation describes, in great detail, each stage in a cross case comparison and grounds each stage of the theory in current research.)

Table four helps the reader see in a holistic manner the participants and their progressions. Upon further analysis it is interesting to explore the patterns which emerge from looking at the holistic table along with the different data sources.

In stage one, hesitations and reservations (anxiety), each of the participants clearly stated their reservations in both the pre interview and again after the initial thirty minute introduction meeting on the first Monday lecture session. This only seems reasonable in that most students experience some reservation and anxiety before and on the first day of class. The anxiety, as stated previously, is usually due to the negative experiences that the preservice elementary teachers had priorly experienced in learning science in formal settings. It is interesting to note that the participants in this study had various experiences before entering the Biology 295 course.

Elly and Jenny both remembered positive science experiences in elementary school. Samantha, Elizabeth, and Natali all remembered elementary science as basically "text book stuff" and they all conveyed that "they really didn't learn anything." Maggie didn't recall any elementary science at all. None of the participants equated a real dislike for the "text book stuff" they experienced during the elementary years; however, the most enjoyable experiences related to the elementary years were invariably connected to activities where the students were actively engaged in what they were doing. Elly mentioned her outdoor leadership camp where she recalled many "science activities relating to nature." Jenny mentioned her Saturday science camp at UNL where there were "tons of hands-on activities." Natali only remembered a "nature walk" with no details. It is also interesting to note that all the participants related their most negative experiences with science during their high school years. This also seems reasonable as the high school experiences, besides college science courses, were the most recent experiences in the participants memory.

After overcoming the initial hurdle of the anxieties, the preservice teachers spent the majority of their time over the next few weeks of journal entries sharing their enjoyment and enthusiasm for learning science, in some cases for the very first time. During this second stage, there were numerous journal entries reflecting the awareness and especially the enjoyment of doing science. Table 4 only displays the most significant journal entries where awareness and enthusiasm were the primary focus of the reflection. The interesting pattern that emerges in this section is that there was a concentration of these journal entries which stayed consistent for about three weeks. The journal entries during this time displayed some interesting characteristics. The words fun, wow, big +, exciting, great, and I really liked, were written with expression. The words were usually capitalized and written in bright colors. In addition, many exclamation points were used to emphasize the enjoyment factor during this time.

An interesting pattern that emerges here is that all of the participants experienced this enjoyment during the same period of time; however, Jenny was a late bloomer. Jenny was science smart and although she enjoyed the labs, her traditional experiences with science somehow seemed to dampen her initial ability to communicate her enthusiasm and enjoyment in her journal. Jenny's reflections about the first few labs were quite rigid and explored only the content and processes that she learned in class. Although Jenny obviously enjoyed the initial labs as noticed from observations, she didn't begin to communicate her enjoyment until about two weeks later than the rest.

Journal entries from all of the participants continued to mention the enjoyment of doing science throughout the entire semester; however, enjoyment and "fun" were no longer the primary focus issue in the reflections after this time.

Stage three or the intrinsic shift was usually a result of the enjoyment combined with the accumulating confidence and realization that the activities done in Biology 295 were actual activities that could be done in the elementary classroom. There came a time when the learning was no longer for the teacher, but for the individual and her future classroom. This shift came at approximately the same time for each of the participants and centered around three events in the class (These events were discussed in detail earlier). The first event consisted of the assigned readings that the students were to read and reflect upon. The second was the Elodea lab where a prolonged amount of time was allotted for the study of photosynthesis in the aquatic plant. The third event was the midterm science fair project/presentation which resulted in a self reflection of the assignment and overall progress in the course up to that time.

The articles allow the students to think seriously about the philosophy toward the teaching and learning of science that they have been experiencing in Biology 295. The photosynthesis and Elodea help the students to realize that they must do their part in learning and not accepting just the "easy answer." Finally, the science fair project allows the students to take both the philosophy and knowledge of learning up to that time and express it in their own experiment. In combination with the enjoyment of science and this application of science that is very personalized, but designed for success, the preservice teachers make the transition from extrinsic motivation to being intrinsically motivated to learn and to do quality work as it has a purpose for their future careers.

Once the intrinsic shift has taken place the fourth stage of rapid growth of self-confidence and self-efficacy takes place. The participants have been developing confidence and efficacy in their abilities both in learning and teaching science since the beginning of the course. However, like stage two, there seemed to be a concentration of reflections ranging from just after midterm to the last week or so in class that focused on confidence and efficacy. In each of the participants reflections there were numerous statements of how for the first time they had "really understood" a topic or concept and that with this understanding they could really "teach it for the first time." Table 4 only shows the most significant reflections for each of the participants in this area. Strikingly, the majority of the reflections appear with the onset of the cell biology unit.

In Biology 295 the emphasis is not on the terminology, but rather the process by which things do what they do. The students identify with both the process and the philosophy and feel confidence in learning about abstract processes which for many is the first time that any of the processes and terminology has made any sense. Each of the participants wrote reflections communicating this confidence regarding the methodology used to teach about cells. Elly, science savvy, wrote, "In less than one hour on a Thursday night in Henzlik, I suddenly UNDERSTOOD AND APPRECIATED material that had definitely been offered to me before." Samantha, science smart wrote, "This lab has been so rewarding to me because I have learned more on the cell, how it works, organelles of it and what it effects, than I have ever learned in high school or college until now." Maggie, science shy, wrote, "I really learned a lot about the cell. I was able to realize the individual parts of the cell, the way it runs (or lives) and the function of each part. Doing a lesson like this enables ease in understanding and retaining more from the activity." Jenny, Science smart, wrote, "For the first time EVER I am beginning to understand the cell. It was always handed to me before and I was expected to know it - now I can actually begin to understand because I have something to connect it to!" Elizabeth, science shy, wrote, "This was a great connection! I was able to understand what a cell does. We knew what a city looked like, a vision and we knew the functions each part played. . . .There was so much that I learned through acting out the parts of the cell." Natali, science savvy, wrote, "Tonite I learned so much about how a cell is comprised. . . I will probably never forget IP on MAT [stages of mitosis] after decorating the cookies."

The reflections to the cell biology lab are only a few relating the confidence and learning that took place during the unit. The gain in confidence and efficacy about teaching and learning science peaked at the end of the semester and resulting in a new stage.

Stage five is the empowerment stage. The participants in this study have progressed through the stages of anxiety, awareness and enjoyment, intrinsic motivation, and rapid growth in self-confidence and self-efficacy, all of which are part of the definition of empowerment. The empowerment stage in Biology 295 is a stage where the preservice elementary education majors have rather full confidence in themselves and their abilities to actually teach science in their future classrooms. All of the students conveyed their attainment of this stage usually in their final journal reflection and then again in the final interview.

The participants explained how they were able to take the lessons to their practicums or other learning environments with children, modify the activity so that it was appropriate for the students in their given situations, teach the concept in a hands-on inquiry manner, and watch the whole process of learning and enjoyment of doing science begin in the eyes of their students. The feeling of being enabled to do science truly becomes empowerment as the preservice teachers teach with confidence and passion and then pass it on to their students. It is interesting to note that the practicum alignment with the Biology 295 course was incidental, but proved to be the major key to the empowerment stage. This only adds to the validity of the argument that you really don't learn or know something until you have to teach it.

Conclusions

In essence, Biology 295 creates an atmosphere for learning science where preservice teachers can capitalize upon their given strengths and learn science in such a way that the preservice teachers then become advocates of science in the schools, a process that probably wouldn't have happened had these preservice teachers taken the "science for the masses" courses where the negative and stereotypical view of teaching and learning science prevail.

Piel and Green (1992) have reported that due to the recent emphasis to improve preservice elementary education majors' science understandings many universities are simply requiring more science courses as prerequisite to entering the professional sequences. In the same study Piel and Green (1992) came to the conclusion that "in spite of highly visible recommendations for more extensive academic course work, results indicate the impracticality of addressing teacher competence through added course work before appropriate attitude adjustment processes have been planned or implemented." The same conclusion was made by Talsma (1996) in her recent study of preservice teachers.

It is important for teacher preparation institutions to recognize that by the time preservice elementary education majors take their science methods course (s) their previous attitudes whether negative or indifferent have been reinforced by the traditional college courses which they have already taken. It is no wonder that so much time in methods courses must be spent initially in convincing the preservice teachers that science is intrinsically interesting.

Based upon the findings presented in this study and related theory of prospective elementary teacher's progression in Biology 295 from anxiety to empowerment in the teaching of science there is no longer any valid justification in assigning "just more content courses." If preservice elementary education majors are to learn science and become science advocates in their future schools, they must first learn to enjoy science and become more confident in their ability to teach science. Thus, one could reasonably conclude that courses should be developed in collaboration with the content areas which replace the general education requirements and yet teach content and pedagogy to these future teachers simultaneously.

This study demonstrates a successful alternative in the learning of content science. Biology 295 has allowed for content and process to be taught simultaneously in a learning environment which enhances preservice teacher's attitudes toward science. This study has theorized the hurdles that preservice teachers overcome in learning content science in order to achieve a positive attitude and confidence toward the subject. This will empower them to teach science in a positive and exciting way so that their future students will not have to overcome the traditional fears and views of science that their teachers may have passed on or may have encountered learning science in a more traditional environment.

Hands-on "type" classes are emerging in colleges and universities across the nation. Numerous funding sources advocate and finance the development of such courses and programs. In a recent study, Wylo (1993) followed recent graduates of elementary education who had experienced a course similar to Biology 295 into their first career teaching assignments. Wylo found that in all of the 38 students surveyed "the positive attitudes acquired in the program persisted over time."

Further research in the validation of the hurdles in learning that preservice elementary education majors encounter as they study science in alternative science courses as well as the long term effects of such courses on professional practice seems to be relevant. Although one study has shown that science instruction improves in the field with such a course, further research and replication studies should be done to explore the long term effects of such theories and programs in practice both inside and outside of the science education community.

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Appendix A - Tables

Table 1: NABT Exam Results.

Section	Pre-Test X	Pre-Test SD	Post-Test X	Post-Test SD	t	p
Fall '95 N = 28	12.32	3.54	16.5	3.24	-6.75	<.001
Fall '95 N = 28	12.61	3.79	17.07	3.75	-7.54	<.001

Table 2: Science Attitudes Survey Results.

variable N = 115	Pre-test X	Pre-Test SD	Post-test X	Post-test SD	t	p	∝ Pre-test	∝ Post-test
Confid	29.33	7.35	35.78	7.59	-9.96	<.001	.87	.89
Utility	32.59	4.88	36.61	5.12	-7.65	<.001	.72	.76
Affect	28.08	8.55	35.9	7.55	-10.04	<.001	.91	.87
Gender	29.47	6.01	31.35	4.64	-3.88	<.001	.88	.86
Constructivism (*)	11.58	2.66	14.21	10.32	-2.67	<.01	.64	.95
Content a	44.81	10.19	51.16	9.32	-6.44	<.001	.91	.92
Content b	43.52	12.16	52.87	10.77	-7.09	<.001	.88	.93

(* Note that the figures in the constructivist column don't make sense due to an error in the reverse coding of the instrument and the statistical interpretation thereof.)

Table 3: Summary of Demographic & Background Information of Participants.

Name	Classification	Town size	Age/ yr	Birth order	Prior science experience
Jenny Case #4	science smart	mid size urban	21 soph	oldest of 4	mixed school experience.
Samantha Case #2	science smart	rural	21 soph	oldest of 3	pretty good school experiences and growing up on farm
Elly Case #1	science savvy	large urban	21 soph	oldest of 4	mixed school experiences
Natali Case #6	science savvy	rural	19 frsh	youngest of 4	neutral or indifferent school experiences. Dad was science teacher.
Maggie Case #3	science shy	mid size urban	40 soph	older middle of 5	no real experience - none remembered. Perceived as negative.
Elizabeth Case #5	science shy	large urban	21 senr	youngest of 7	bad school experience

Table 4: Overview of participant stages and reflections in the substantive theory.

Name	Hesitation/ Reservation	Awareness & Enjoyment	Intrinsic Shift	Confidence / efficacy	Empowerment
Jenny	Pre Interview 1/9/95 (1)	1/30/95 (4) 2/10/95 (9) 2/13/95 (10) 2/23/95 (22)	2/25/95 (25) 3/2/95 (26) 3/9/95 (40)	3/30/95 (46) 4/6/95 (66) 4/13/95 (75)	5/1/95 Final Journal Entry (FJE) 5/1/95 (82) End note Post interview
Samantha	Pre Interview 1/9/95 (1)	1/14/95 (3) 1/16/95 (7) 1/19/95 (8)	3/9/95 (23) 3/9/95 (25)	4/6/95 (31) 5/1/95 (37)	5/1/95 (FJE) Post interview
Elly	Pre Interview 1/12/95 (1)	1/13/95 (4) 1/19/95 (8) 1/26/95 (12)	2/23/95 (31) 3/7/95 (37)	3/13/95 (40) 4/24/95 (50)	5/1/95 (FJE) Post interview Artifact
Natalie	Pre Interview 1/9/95 (1)	1/12/95 (2) 1/16/95 (3) 1/19/95 (6)	3/2/95 (35)	4/6/95 (47) 4/13/95 (50)	5/1/95 (54) (FJE) Post interview
Maggie	Pre Interview 1/9/95 (1)	1/13/95 (3) 1/20/95 (7)	2/9/95 (20) 3/9/95 (37)	2/28/95 (34) 3/16/95 (44) 5/1/95 (58)	5/1/95 (FJE) Post interview
Elizabeth	Pre Interview 1/9/95 (1)	1/12/95 (3) 1/20/95 (6) 1/20/95 (7) 1/26/95 (11)	3/9/95 (48) 3/9/95 (49)	3/9/95 (49) 4/6/95 (57) 4/27/95 (69)	5/1/95 (72) (FJE) Post interview

TRANSLATING CURRENT SCIENCE EDUCATION REFORM EFFORTS INTO CLASSROOM PRACTICES

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Introduction

In the mid-1980s, for a second time in this century, a crisis was declared in science education. It became apparent from reports based on national assessments of science that there was a major problem in science education in elementary and secondary schools (e.g., Boyer, 1983; National Commission on Excellence in Education (NCEE), 1983). Several studies revealed that there was a decline in achievement and interest in science, and in the understanding of basic science concepts (National Assessment of Educational Progress (NAEP), 1983, Hueftle, Rakow, & Welch, 1983; Weiss, 1987). Most high school graduates and even college students could not apply their science knowledge to real life situations (Champagne & Klopfer, 1984; Yager & Penick, 1987). Further, reports on international comparisons of student assessments also revealed that American students did not measure up to students in other developed countries in science and mathematics (International Association for the Evaluation of Educational Achievement, 1988; Klein & Rutherford, 1985; Lapointe et.al., 1989). The problem was not limited to science education alone; the 1983 NCEE report painted a grim picture of the state of education in the nation. In some cases, the problems in education were linked to a corresponding decline in America's leadership position in economics, and scientific and technological advances (e.g., Center for the Assessment of Educational Progress, Educational Testing Service, 1987). The educational system was failing in its task of preparing students for responsible citizenship and productive employment. There was a national outcry for educational reform and for reform in science, mathematics and technology education.

In response to the nations' call for action the American Association for the Advancement of Science initiated a comprehensive long-term reform effort, Project 2061. This project proposed a fundamental reform of science education focused on achieving scientific literacy for all Americans. The efforts made by AAAS produced two documents, *Science for All Americans* and *Benchmarks for Scientific Literacy* which are now being used widely by various groups working on science reform at state and national levels.

Today, science, mathematics, and technology education are deemed as very important disciplines in American education. These disciplines are now seen as important for all citizens to participate effectively in a highly scientific and technological society. Thus, a major goal of science education today is science literacy for all Americans. In an effort to achieve this goal, large amounts of financial and human resources are being used all over the nation to restructure, and redesign K-12 science education. New programs are being designed and implemented at the elementary, middle school, and high school levels.

Following the publication of *Science for All Americans,* which defined scientific literacy, the National Research Council coordinated the development of national science education standards. *The National Science Education Standards* describes what students should understand and be able to do at different grade levels and in various branches of science. The *Benchmarks for Scientific Literacy* and the *National Science Education Standards* now serve as blueprints based on which individual states are developing their science education standards.

The Outstanding Schools Act (Senate Bill 380) is the spring board from which reform efforts were launched in Missouri. Senate Bill 380 was passed into law by Missouri Legislature in 1993. Among several new programs and policies the law called for the establishment of academic performance standards that all students should obtain before graduating from high school. The standards would then serve as a basis for a revised statewide testing program and a guide for school curriculum. Within the context of this law reform in science education was initiated and new science standards and curriculum frameworks are being developed.

As stated in the *National Science Education Standards*, "the real journey of educational reform and the consequent improvement of scientific literacy *begins* with the implementation of these standards" (p. 243). Defining scientific literacy and mapping out what it means to be scientifically literate are only the beginning of a long journey through the reform process. The most difficult task in an education reform effort of this nature is implementation. First, there is an urgent need to provide professional development experiences for teachers that will enable them to implement the new standards. Second, teacher education institutions need to provide learning experiences within their programs that will effectively prepare beginning teachers to implement the new standards. The project described in this paper focuses on the former.

Description of the Project

This is a first year report of a teacher enhancement project at Southwest Missouri State University funded by Missouri's Higher Education Eisenhower Grant Program. The purpose of the project was to provide professional development experiences for teachers that will enable them to implement the new national and state standards.. The goals of the project were:

1. To provide teachers with a vision of the science teaching and learning standards contained in the *Benchmarks for Scientific Literacy*, *National Science Education Standards*, and *Missouri Academic Performance Standards for K-12*.
2. To provide teachers with knowledge and skills that would enable them to implement the standards described in these documents.

The project consisted of five weekend workshops scheduled during the 1995/96 academic year. Each workshop lasted for a whole day on Friday and half a day on Saturday. In these workshops, information about the content of the reform documents was provided and teachers were engaged in hands-on activities, inquiry, discussion, and development of curricula materials. The workshops were spread out through the year to give teachers enough time to reflect on new knowledge, practice new skills and try out new ideas.

Participants received a total of 60 hours of instruction. Graduate credit was made available to teachers who opted to participate in the project for credit. The project director, who is a science educator in the Physics Department and a science educator in the Biology Department, were responsible for the instruction, supervision, and mentoring in the project.

The target group was grades 4-8 teachers in rural schools. Rural teachers were targeted because they typically do not have the financial or human resources to embark on large scale reform efforts. Teachers were recruited from the southwestern region of Missouri through a variety of recruitment procedures. Thirty teachers were recruited. However, six teachers dropped off after the first or second workshop due to health problems, family problems, and/or pressure of work at school. Thus, 24 teachers completed the project. The teachers were from 13 school districts and one private school. There were 15 elementary teachers, eight middle school teachers, and one secondary level teacher. The elementary grade teachers were in self contained classrooms but the others were not. The group consisted of 21 females and three males.

Overview of Project Activities

The topics covered in the workshops were selected based on the science content standards, science teaching standards, assessment standards, and science program standards described in the *National Science Education Standards*. Participants prepared, taught, self evaluated, and revised sample lessons, units, and modules throughout the project. At the end of each workshop the participants were given assignments which focused on encouraging them to implement the knowledge and skills learned at that workshop.

First Workshop - September, 1995

At the first workshop, teachers were provided with information about the *Benchmarks for Scientific Literacy*, *National Science Education Standards*, and the *Missouri Academic Performance Standards*. They worked in grade level teams in discussing the similarities and differences between the content standards and their current science curriculum and identified topics and skills that were not being addressed in their classes. Information was presented on meaningful versus rote learning and constructivism. Different teaching methods were discussed including strategies and techniques that enhance learning. The Learning Cycle was modeled and the participants analyzed, discussed and critiqued the lesson. Finally they worked in collaborative groups in developing ideas for a grade level appropriate learning cycle lesson. Each participant had to teach and self evaluate at least one learning cycle lesson in his/her classroom before the next workshop.

The workshop ended with a brief a presentation on the philosophy, methods, and typical examples of action research. The purpose was to provide participants with some background knowledge that will enable them to identify possible topics for investigation in their classroom or school.

Second Workshop - November, 1995

At the beginning of the second workshop, teachers were given an opportunity to share their experiences in teaching the learning cycle lesson. Then a discussion was generated on possible action research topics and questions related to methodology were discussed. Other topics addressed in the workshop were journaling and concept mapping. Participants were taught how to draw concept maps and how to teach concept mapping to students. At the end of the workshop, the participants were asked to introduce journaling and concept mapping in their classes and to report on their experiences at the next workshop. The issue of diversity in the classroom was also addressed in the second workshop. Information on the varieties of learning and teaching styles and *The 4-MAT System* were presented. Techniques for teaching science to students with special needs were also discussed.

The next day, inquiry teaching was modeled and participants experienced what is involved in inquiry teaching and learning. The participants then developed inquiry lessons which they taught and self evaluated when they returned to their classrooms.

Third Workshop - January, 1996

The focus on the first day of the third workshop was on problem solving, critical thinking, and integration. Teachers participated in hands-on problem solving activities which enabled them to understand the differences between a science experiment and a problem solving activity. Different types of problem solving activities and how they can be used in the classroom were presented. Integration of the sciences and integration of science with other subjects was discussed Again, teachers participated in hands-on activities that demonstrated integration. Some of the activities were done outdoors to show how the outdoors can be used as a science classroom. Following the presentations, participants worked collaboratively in developing grade level appropriate integrated thematic units.

The focus of the Saturday morning session was on assessment. Different assessment strategies were presented. Participants worked on a hands-on activity which involved the development of a rubric. Following the presentation the participants worked collaboratively in developing assessment tasks for the unit that was developed the previous day. The assignment at the end of the workshop was for the participants to teach and self evaluate the thematic unit that was developed including all of the assessment procedures that were designed.

Fourth Workshop - March, 1996

The Friday morning session of the fourth workshop was used to reinforce, extend, and apply the knowledge and skills that were taught during the first three workshops. The workshop started with feedback from the participants on the thematic unit. Difficulties and problems were addressed and possible solutions were discussed. Using concept maps obtained from the students of one of the participants, techniques for scoring concept maps were discussed. Participants practiced scoring the maps and issues arising from the scoring techniques were discussed. The topic of diversity was visited again but the focus in that workshop was on strategies for developing interest of girls and minorities in science. Later that afternoon the group was taken on a field trip to a school where a middle school science teacher demonstrated some of the ways in which technology can be used effectively in the science classroom. The Saturday session was devoted to the development of a teaching module that incorporated all of the science teaching methods, techniques, and strategies that were presented in the workshops. They also had to align and cross reference the topics chosen with the Benchmarks and the national and state standards. Participants were required to teach and self evaluate some of the lessons in the module before the fifth workshop.

Fifth workshop - May, 1996

At the beginning of the workshop, participants reported on the lessons that were taught from the module. A lot of feedback and discussion was generated as participants reported on their experiences. Later a model for science curriculum development was presented based on the skills that the participants had developed throughout the workshops. They then worked in collaborative groups in planning a science curriculum framework based on science teaching modules. The instructors worked with the groups to ensure that the content was aligned with the standards and that the new methods, skills, and techniques learned in the workshops were included in the plans.

The next day, each participant gave a report on the action research project that they embarked on during the year. Then, each grade level team presented their curriculum framework plan and the participants talked about how this experience would be used to enhance the curriculum planning and development in their school or district.

Between March and May 1996, each participant was observed while teaching a science class by one of the two project instructors. Time was scheduled before or after the class for discussion with the teacher. Issues related to the implementation of the new ideas were discussed. After observing the class the teacher was also provided with feedback that highlighted the strengths and included recommendations for improving the weaknesses.

Evaluation Procedure

A variety of assessment and evaluation procedures were used. The evaluation procedures were comprised of: 1) the use of surveys that were administered at the beginning and the end of each workshop and others that were administered at the beginning and end of the project, 2) classroom observations, 3) interviews and conversations with teachers, 4) journals, and 5) continuous assessment of products of group and individual tasks throughout the workshops. Ten questions were generated. The questions that were addressed and the procedure(s) used for collecting information are included in the next section. The data collected was analyzed to generate some answers to the questions. The results are discussed with reference to each of the questions.

Results

Question 1

What do the participants know about the Benchmarks for Scientific Literacy, the National Science Education Standards, and the Missouri Performance Standards?

Data obtained from the pre and post surveys are reported in Tables 1 and 2.

Table 1
Results of Teacher Reports on Knowledge about the Benchmarks for Scientific Literacy, the National Science Education Standards, and the Missouri Show-Me Standards

N=30	Before Science Reform Workshop			After Science Reform Workshop		
Knowledge of:	None or Very Little	Some	A Lot	Very Little	Some	A Lot
Benchmarks	67%	23%	10%	10%	47%	43%
Natnl. Standards	60%	37%	3%	10%	40%	50%
MO Standards	40%	57%	3%	27%	30%	43%

Table 2
Results of T-test on Teacher Knowledge Data

	Mean		S. D.		
N=30	Pre	Post	Pre	Post	t-value
Benchmarks (Scale 0-3)	1.04	2.38	1.04	0.62	7.21*
Natnl. Standards (Scale 0-3)	1.23	2.50	0.82	0.63	7.33*
MO Standards (Scale 0-3)	1.38	2.11	0.90	0.83	5.02*

* $p < 0.001$

All of the comparisons were significant at the 0.001 level. Thus, there was a statistically significant increase in participants, knowledge of the Benchmarks, the National Standards, and the Missouri Standards.

Question 2

What changes do teachers experience in their attitudes to teaching science?

A survey was used to collect information on teachers' views about science teaching before starting the project and at the end of the project. A 0-10 scale was used on the survey. The higher the number the better the attitude it represented. The results are reported in Table 3.

Table 3
Change in Teachers' Views about Science Teaching

	Mean		S. D.		
N=20	Pre	Post	Pre	Post	t-value
Teachers' views on teaching science	5.70	7.13	2.30	1.14	3.15*

* $p < 0.01$

The computed t-value was significant at the 0.01 level. Therefore, there was a significant positive change in teachers' views about science teaching.

Question 3 - 4

Questions 3 & 4 were evaluated qualitatively through observations and informal conversations.

Do science teaching attitudes correlate with practices in the science classroom?

Are teachers implementing new classroom practices in their classrooms?

Observations revealed that about seventy percent of the teachers were very open and receptive to the new ideas. They made every effort to try out the new techniques and methods in their classrooms. In several cases they did more than what was required in the project. A few teachers were rather skeptical about whether some of the new ideas will make a difference with regard to students learning. The teachers that were more open to change implemented more of the new ideas and provided lots of feedback and generated discussions based on their experiences.

The more skeptical teachers implemented the ideas with some anxiety and were not confident in using the skills or methods. However, when they did they were surprised at the response of the students. They reported that students reacted positively to the lessons.

The project was designed in such a manner that teachers were forced to try out new skills and strategies after learning them. All of the teachers experienced some change as they implemented the ideas. Teachers that had a more positive attitude towards reform in science education implemented the new ideas more frequently.

Question 5 - 7

Data from the pre and post survey was analyzed to provide answers to questions 5 through 7. Table 4 contains the results of the analyses.

Are teachers engaging students in constructing scientific concepts?

Are teachers engaging students in problem solving and critical thinking activities?

Are teachers implementing alternative assessment procedures?

The results show that there were significant changes in teachers' use of constructivist practices in their classrooms. There were also significant changes in teachers' use of problem solving and alternative assessment strategies.

Table 4
Teacher Change with Regard to Use of Constructivist Teaching, Problem Solving, and Assessment

	Mean		S. D.		
N=20	Pre	Post	Pre	Post	t-value
Constructivism (Scale 0-10)	4.72	6.40	1.69	1.02	4.11*
Problem Solving (Scale 0-4)	2.84	3.10	0.88	0.59	4.45*
Alt. Assessment (Scale 0-4)	1.70	3.10	0.98	0.72	4.91*

* $p \leq 0.001$

Table 5
Teacher Change with Regard to Knowledge of Constructivist Teaching, Problem Solving, and Assessment

	Mean		S. D.		
N=19	Pre	Post	Pre	Post	t-value
Constructivism (Scale 0-3)	1.38	2.30	1.03	0.60	5.41**
Problem Solving (Scale 0-3)	1.90	2.41	0.82	0.51	3.10*
Alt. Assessment (Scale 0-3)	1.79	2.53	0.90	0.51	4.24**

*p < 0.01

* *p ≤ 0.001

Data from pre and post workshop surveys provided some information about changes in teachers' knowledge about these teaching strategies. Results obtained from pre and post workshop surveys on teachers' knowledge about constructivism, problem solving, and critical thinking, and alternative assessment are reported in Table 5.

The results in Table 5 show that there was significant increase in teachers' knowledge about these methods and techniques. The increase in knowledge must have resulted in the increased use of these strategies in the classroom.

Question 8 - 10

Questions 8, 9, and 10 were evaluated using information obtained from classroom observations, teachers' journals, and informal interviews.

What are teachers' views about the networking mechanism established in this project?

Teachers were very receptive to the networking mechanism that was set up through the project. They constantly commented on the opportunity that the project created for the exchange of ideas among the participants and between the participants and instructors. The relationships that were established will last long after the end of the project. Teachers are still keeping in touch with the instructors and seeking help in a variety of ways. A name and address list was distributed at the end of the project to encourage participants to keep in touch with each other.

To what extent are teachers using research and other strategies to reflect on and generate knowledge about the teaching and learning process in their classrooms?

Each participant embarked upon an action research project. The degree of involvement in the research project varied from one participant to another. However, even those that did very small projects reported on insight that they gained from the problem that they studied. After the first experience some say they now feel more comfortable to engage in other research studies. Some teachers are currently involved in ongoing projects that may continue for another year or so.

To what extent are teachers able to apply the knowledge, skills, techniques, and strategies learned in the workshops?

All of the evidence obtained from the various evaluation methods indicate that teachers have been making every effort to implement the knowledge, skills, techniques, and strategies that they learned in the workshops. It was not expected that 100% of the participants will implement 100% of the ideas. However, enough of the knowledge and skills has and will continue to be implemented for one to say that change has been effected.

Some teachers are already leading reform efforts in their schools and districts. They are giving presentations, planning workshops, and leading curriculum development efforts in their school districts. About six of the participants will return as lead teachers to participate as co-presenters and facilitators in the project this year.

Conclusion

Experiences from this project reveal that teacher change occurs when teachers first of all see the need for a reform, and then acquire the knowledge and skills necessary to bring about a change in their attitudes, teaching philosophies and teaching practices. Teachers in the project became familiar with the teaching and learning standards described in the reform documents and as they reflected on their science teaching and science programs with reference to these standards they saw the need for change. The project provided them with various experiences through which they acquired the knowledge and skills that enabled them to make changes in their teaching practices. Some of the teachers have emerged from the experience as change agents and are currently initiating reform efforts in their schools and/or districts. Thus, the project was quite successful in taking the current reform in science education into the classroom in its first phase of implementation. Change in education does not occur overnight, it is usually a slow process. It may take a decade or more for the full effects of some of the current efforts to be realized. As the project continues, the long term effects of the project on the participants will be studied over the next few years.

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VALUES, DISSECTION, AND SCHOOL SCIENCE: AN INQUIRY INTO STUDENTS' CONSTRUCTION OF MEANING

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Rationale

Facilitating the development of scientific literacy in students has been identified as one of the most important tasks facing science educators today (American Association for the Advancement of Science, 1993; 1989; National Science Teachers Association, 1992). An understanding of the nature of science is regarded as one of the defining characteristics of scientific literacy (National Research Council, 1996; American Association for the Advancement of Science, 1993; National Science Teachers Association, 1992; Lederman & Zeidler, 1987; Showalter, 1968). Moreover, the importance of a philosophical view of the nature of science has had a presence in the science education community since the writing of Kuhn (1962), Schwab (1962) and Rutherford (1964) over thirty years ago. In its current incarnation, the "nature of science" has come to emphasize scientific inquiry as a human endeavor which is uncompromisingly bound to personal values and assumptions (Lederman, 1992).

Though the discipline of science education embraces the notion that human values are inherent in the enterprise of science, translating this ideology into the practice of teaching is a somewhat more problematic issue. Roth (1992) and Tobin (1991) suggest that the epistemology underlying most traditional practice in science classrooms is objectivism, which manifests itself in the teaching of science as a body of objective facts. Teaching science from this objectivist stance contradicts the philosophical basis of the nature of science.

Tobin, Tippins, and Hook (1992) contend that despite the adoption of perspectives consistent with the nature of science, many studies fail to account for the contribution of social and cultural factors in determining the negotiated meanings between the stakeholders in the classroom.

purpose of this study is to identify and explore the intersection of students' values and those inherent in the activity of dissection.

Background

Values, along with attitudes, beliefs, opinions, interests and motivation are among the components that constitute the affective domain (Simpson, Koballa, Oliver & Crawley, 1994). The generative role of values in the formation of more specific attitudes and beliefs emphasizes its significance both among the components of the affective domain and in the study (Rokeach, 1973).

Values can be distinguished from attitudes and beliefs. An attitude is an evaluation of some object about which an individual has some knowledge (Pratkanis, Breckler, & Greenwald, 1988). Attitude reflects one's disposition toward an idea. This construct represents a favorable or unfavorable feeling toward something (Koballa, 1989). Beliefs form the cognitive basis for attitudes and are situated among more informational and factual components of thought.

Definitions of values are vary widely in their specificity and content. For example, Kilby (1993) defines a value as anything of importance to a person. However, Rokeach (1973) defines a *value* as an enduring belief that a specific mode of conduct (honesty) or end-state of existence (success) is personally or socially preferable to an opposite or converse mode of conduct or end-state of existence.

Values are described as broad, abstract goals that lack a specific object (like attitudes) or reference point. Bravery, beauty, freedom, and practicality are values. They serve as dimensions of judgment or as abstract standards for decision making, through which an individual may develop specific attitudes and beliefs (Rokeach, 1973).

For example, if *beauty* is a primary value for a particular individual, many of his attitudes and beliefs may be based on judgments as to whether a particular object is beautiful. The value of practicality may be more important to another individual, and many of her beliefs and attitudes may be based on judgments as to whether a particular object is practical. With this in mind, the two individuals' attitudes and beliefs regarding a particular object may differ sharply. The term *values* has come to mean the principles, ideals, and desire that constitute the basic motivational structure of a person or culture (Winner, 1986).

The study of values is complicated by their tacit nature. Accordingly, direct inquiry into an individual's value systems is not likely to be fruitful. For example, if an interviewer posed the question, "What are your values?" it is probable that any given respondent would be able to think of very few, and these would likely be restricted to moral values. Even though each individual possesses many values, they are expressed contextually— through life experiences rather than in conscious thought. Because of the implicit nature of values, they are not readily accessible to the conscious awareness, and as such they cannot be measured directly. However, because values are expressed through our thoughts, behaviors, attitudes, etc. they are readily accessible through interpretive methodology.

A working understanding of the role of value systems in shaping attitudes, feelings, and behaviors is critical to the interpretation of the data. Williams (1968) describes the nature of value systems in the following:

> ...[perceptions] are steered by multiple and changing clusters of values. After a value is learned it becomes integrated somehow into an organized system of values wherein each value is ordered in priority with respect to other values. Variations in personal, societal, and cultural experience generate individual differences in value systems (p. 287)

According to Williams, values are arranged into hierarchical clusters, which are determined and organized by socio-cultural factors. These clusters of values, or "value systems" function in such a manner that at any particular time, a single value or set of values has priority status in influencing an individual's attitudes and behaviors. However, the priority status of a value is contingent upon the particular phenomenon or context in which the phenomenon occurs. Changes in phenomena and shifts in context may cause a predominant value to shift in priority, wherein it is superseded by a different value or set of values.

An individual's predominant values are highly influential in determining his or her perception of a particular phenomenon. In this context, "perception" is offered as a simplified descriptor of the "meaning assigned to" a phenomenon. Quintas (1989) describes the essence of meaning in the following way:

> The scope of the term "meaning" is far wider than that of "significance." An action may entail very precise and even outstanding significance and still not have meaning because it is not integrated within an overall value horizon. Action endowed with significance may acquire positive or negative meanings in different contexts (p. 85).

In other words, phenomena are assigned meaning through the organizational scheme that characterizes the individual's system of values and according to the context in which they occur. Much of the study data is interpreted according to this working framework of values, value systems, and perceptions.

Purpose

This study represents an investigation of the values embedded in the activity of dissection and how those values relate to the personal values of individual students. Additionally, the study explores the implications of this value relationship in students' assignment of meaning to the science they learn in high school. By emphasizing the relationship of these two independently constructed value systems, the research focuses on the human connection between science and science learning. The research questions guiding the study were: 1. What major factors in the life experiences of the students (gender, religion, past experience) contribute to the development of their value systems related to the dissection experience; and 2. How do the students' personal values compare and contrast with those found in the secondary science curriculum? We hope that developing a richer understanding of this value-centered relationship will help promote the teaching and learning associated with the activity of dissection into a more positively meaningful experience for all.

Conceptual Framework

Critical theory (Apple, 1979; Giroux, 1983), social constructivism (vonGlasersfeld, 1987), and world view theory (Cobern, 1991) together constitute the theoretical foundation of this endeavor. By recognizing these particular frameworks, I identify the lenses through which I view, collect and interpret data. These frameworks provide the focus and direction of the study. The use of multiple frameworks reflects an agreement with Denzin (1978) who advocates a triangulation of theoretical frameworks as a method of cross-verifying the perspective of the researcher.

It is useful to think of critical theory as a unifying perspective which is grounded in the social constructivist framework and elaborated upon by the world view framework. Critical theory rejects the idea of an isolated, objective reality and advances a conception of reality that is collaboratively constructed in concert with socio-historical influences (Gallagher, 1993). Generally speaking, social constructivism is defined as a theory of knowledge that emphasizes the personal and individual construction of understanding based on social experiences. This concept of social knowledge establishes an epistemological foundation from which critical theory may proceed. Simply stated, constructivism describes understanding as a highly social process, and critical theory provides the means by which individuals can pursue this personal understanding by exploring its social and historical derivation. World view theory serves to sharpen the focus of the conceptual frame by highlighting the significance of the specific socio-cultural elements embedded in the dissection experience.

Cobern (1991) has defined world view as a culturally-dependent, implicit, fundamental organization of the mind, composed of presuppositions or assumptions which predispose one to feel, think, and act in predictable patterns. The formation of world view begins in childhood, and through the myriad of interactions with the physical and social environment, world view presuppositions are unconsciously constructed. The world view of any given culture is invisible, existing almost exclusively in the subconscious of its members. Over 30 years ago, Hall (1959) wrote that "Honest and sincere men in the field [of sociology] continue to fail to grasp the true significance of the fact that culture controls us in deep and persisting ways, many of which are outside of awareness and therefore beyond conscious control."

Skow, Samovar, & Heilweg (1990) emphasize that the world view of an individual becomes particularly influential when issues such as religion, death and suffering, humans' place in nature, and other questions of "being" are considered. As these “critical” issues correspond so closely with those embedded in the conflict surrounding the activity of dissection, world view theory provides particularly suitable theoretical grounding for the discourse of the study.

Methods

The study site is a tenth grade biology classroom in a high school located in the rural southeastern United States. The school has approximately 600 students in grades nine through twelve. The instructor of the course, Mr. Bradley is an experienced teacher who frequently uses animal dissection as a method of instruction. Participants in the study are comprised of the 85 students in his enrolled in Mr. Bradley's basic and intermediate biology courses. A purposeful sampling strategy was employed in order to select key participants that were most likely to provide the richest information for the study. During the initial stage of the study, students were informally engaged in conversation during laboratory activities. These conversations generated information regarding students' attitudes and beliefs about dissection as well as their individual levels of reflectiveness. Seventeen students were selected to participate in first round interviews. Students were selected for interviews according to their willingness to participate and their level of reflectiveness. Students participating in each round of interviews represented a balance of positive, neutral, and negative attitudes towards dissection. From this initial group of 17 students, eight were selected for more in-depth follow-up interviews. Four of these students also chose to participate in the third and final round of interviews.

The data collection methods chosen for the study were participant observation, in-depth student interviews, and videotaping. These particular methods were selected for their potential to provide the richest data as well to emphasize cross-verification of the data sources.

In the first weeks of the study, my role in the laboratory classroom was primarily observational, but as I observed and talked with students, I increasingly found situations arising that compelled my assistance. Consequently, my role in the classroom slowly evolved into one of a "second instructor." As such, my responsibilities expanded to include assisting students, grading papers, and setting/cleaning up the lab between classes. This role also helped to establish a comfortable rapport and level of trust with the students and the instructor, which in turn facilitated data gathering.

Interpretive research is by nature constantly comparative. Constant comparative methodology adopts the stance of always questioning gaps, omissions, inconsistencies, misunderstandings, and not-yet complete understandings (Glaser & Strauss, 1967). As a researcher working in this context, data was collected, coded, and analyzed as a ongoing process. On several occasions, a co-researcher independently collected data at the research site. The understanding generated through discussions with the co-researcher as well as the instructor of the course added significant insight to the analysis of the data. The primary analysis of data served to direct and focus the subsequent levels of data collection. As data collection drew to a close, insight and awareness into the data coalesced into a deeper understanding and appreciation of the dissection experience. This understanding evolved as all of the "pieces" from the data analysis were brought together and constructed into a more meaningful and holistic picture of the phenomenon.

Nature of the Data

Data from the participant observation method was collected in the form of field notes. Observations included actions and language, as well as more subtle cues such as facial expressions, gestures, tone of voice and other unverbalized social interactions which suggest tacit meanings.

Interviews were structured according to the *interview guide approach* outlined by McMillan & Schumacher (1989). According to this approach, the researcher asks questions concerning predetermined topics, but has freedom to choose the sequence and wording of the questions as the interview progresses. Questions were asked in a open-ended manner that allowed the students a great degree of latitude to pursue a range of ideas and to shape the content of the interview (Bogdan & Biklen, 1992). Probing and clarification questions were used to uncover specific meanings suggested by, but not fully developed in the participant's answers (Patton, 1990). All interviews were tape recorded and transcribed for data analysis. In order to preserve the essence of the participants' wording, interviews were transcribed verbatim.

The initial interview protocol was composed of five broadly worded, open-ended questions. For example, the first question of the protocol was simply, "How do you feel about dissection?" As the initial interviews and field notes were analyzed, the ideas that were most relevant to students' perception of dissection were included in the protocol of subsequent interviews. Through this constantly comparative process, well supported ideas were carefully developed and explored through more detailed questioning, while ideas that could not be supported were abandoned.

Upon the completion of the interviews, the protocol questions were developed into corresponding items on a survey instrument (See Appendix A). The five response categories on the survey ranged in agreement from "strongly agree" to "strongly disagree." The thirty-five item survey instrument, along with a well-established "attitudes toward dissection" (Strauss & Kinzie, 1991) survey were administered to all eighty five students in the study. Descriptive statistical analysis of the survey data is used to elaborate and enhance discussion of the qualitative data.

Many of the laboratory sessions were videotaped. Videotapes were used as a secondary source of information. In order to minimize intrusiveness, the camera was secured on a tripod in a front corner of the classroom. Because of this limitation, only the loudest dialogue on the tapes is audible. Videotapes were analyzed for student positioning relative to dissection materials, gesturing, and their behavior toward one another and the animals they were dissecting. The narrative descriptions generated from the videotapes served to verify, elaborate, and enhance the dialogue from the students' interviews.

Discussion of Findings

Extensive analysis of interview transcripts, field notes, and video-taped laboratory sessions revealed several major patterns in the data which were framed and supported by numerous minor patterns. Patterns revealed through data analysis are characterized by reoccurring thoughts, beliefs, attitudes, or feelings experienced by the students as they reflect on the dissection experience.

The results of this study are organized around four dimensions that emerged from the various data sources. These dimensions, when taken together, create a multifaceted tool for viewing the dissection phenomenon. The first and most fundamental of these dimensions centers on the moral issues prevalent in the minds of students as they reflect on the dissection experience. These moral issues include: the killing of animals; acceptable treatment of the dead; cultural taboo; and reflections on self. The second dimension concerns epistemological issues associated with dissection. These issues include: the empirical nature of dissection; the development of intellectual independence, discovery learning; investigation; elaborating on text information; development of a more holistic understanding; and hands-on learning. The third dimension explores the physical issues associated with the dissection experience as it is unfolds in the classroom. This dimension is generally expressed as students negatively perceive and reflect upon the immediate physical presence of dissection. Finally, the fourth dimension focuses on the issue of familiarity as it relates to dissection. Discussion in this dimension focuses around: positive or neutral everyday experiences with dissection; negative everyday experiences with dissection; and other familiar experiences relevant to dissection.

These four dimensions are not intended to stand alone as independent categories within the data. Rather, they represent a subjective construction of an organizational scheme intended to guide the discussion of the data. In students' real-life cognitive, affective, and physical interaction with the phenomenon of dissection, none of these dimensions exists in isolation from any other. Rather, it is the intertwining and overlapping of these dimensions that form the essence of the dissection experience for the participants.

In brief, students' perception of the dissection experience was contingent on the consistency (or lack thereof) of their personal value systems with the underlying beliefs found in each of the four dimensions of dissection. Students' attitudes are affected by the beliefs (and their underlying values) in varying degrees, and many times their influences are overlapping.

Along the four dimensions, students' perceptions of dissection are expressed in terms of their position on seven belief statements. The belief statements were inductively generated through extensive and prolonged analysis of data. These seven beliefs represent what the researcher feels are implicit in the activity of dissection. Periodically, survey items are provided to give an overview of general student responses. As stated earlier, survey items are constructed directly from *students'* narrations of their thoughts, beliefs, and attitudes.

The killing of animals for the purpose of learning is a justifiable and acceptable behavior is the first belief embedded in the dissection experience. Students' beliefs about killing generally fell into three categories, each with a range of agreement: 1) killing can be fun; 2) killing is acceptable with good reason; and 3) killing is objectionable. Students agreeing with the first two of these beliefs are most likely to have a positive experience with dissection.

The survey instrument contained two items corresponding to the first belief statement, "killing can be fun." On the survey instrument 40% of the 85 students responded that they agreed or strongly agreed (hereafter referred to as "agreement") with the statement, "It can be exciting to kill animals for food (like deer)," and 38% agreed or strongly agreed with the statement, "It can be exciting to kill animals that are dangerous (like snakes)."

Seventy-three percent of the students were in agreement with the statement, "I feel okay if an animal is killed as long as it is for a good reason," and no one strongly disagreed with the statement. This item corresponds with the second belief statement, "killing is acceptable with good reason."

On the survey instrument, 22% of the students were in agreement with the statement, "I am opposed to killing animals," and 26% of the students responded that they were undecided on the issue. This item corresponds with the third belief statement, "killing is objectionable."

Touching the dead body of an animal is a socially and culturally acceptable behavior is the second belief inherent in dissection activities. Student beliefs about this social and cultural acceptance generally fell into two categories: 1) dissection is uncomfortable because cutting open dead animals is a socially unacceptable behavior; and 2) dissection is exciting because cutting open dead animals is socially unacceptable behavior. Students who agreed with the second axis were more likely to have a positive experience with dissection, however, this factor was not relevant to a large number of students (57%).

On the survey, 23% of the 85 students responded that they agreed or strongly agreed with the statement, "Sometimes dissection is difficult for me because the way I was raised, you're just not *supposed* to be cutting open dead animals." Similarly, 20% of the 85 students were in agreement with the statement, "Dissection is exciting because we get to do something that we aren't *supposed* to do."

The third belief is that *the greater the similarity between the body of the animal and the human body, the greater the gains in understanding of human anatomy*. Student beliefs generally fell into three categories of agreement. As the animal's body more closely resembles a human: 1) dissection becomes more exciting; 2) dissection becomes more disturbing; and 3) I feel like I learn more. Students falling into the first and third categories are more likely to have a positive experience dissecting more human-like animals (note: these categories are not mutually exclusive).

On the survey, 43% of the students were in agreement with the statement: "As an animal's body more closely resembles the human body, dissection becomes more exciting" and 64% were in agreement with the statement "As an animal's body more closely resembles the human body, I feel like I learn more." Conversely, 35% of the students responded positively to the statement "As an animal's body more closely resembles the human body, dissection becomes more disturbing."

Cutting apart, probing, and pinning is acceptable treatment of a dead animal's body is the fourth belief associated with dissection. Student beliefs fell into the categories of: 1) moral consideration is extended to dead animals; 2) limited moral consideration is extended to dead animals; and 3) once the animal has died, moral consideration of it no longer relevant. Students agreeing with the second and third beliefs are more likely to have a positive experience with dissection.

Thirty-five percent of the students were in agreement with the statement, "During dissection, I feel like I'm being disrespectful to the animal," and 37% were in agreement with the statement, "Sometimes during dissection, I feel like I'm hurting the animal." These items correspond with the belief that moral consideration is extended to dead animals.

Conversely, 48% of the students disagreed with the statement, "During dissection, I feel like I'm being disrespectful to the animal," and 48% disagreed with the statement, "Sometimes during dissection, I feel like I'm hurting the animal." These items correspond with the belief that moral consideration is not relevant to dead animals.

Interaction between students and the dissection specimens will result in their gaining understanding of the structure and function of the animal's internal anatomical structures is the fifth belief. Student beliefs fell into two categories: 1) I feel like I learn from dissection; and 2) dissection does not help me learn. Students falling into agreement on the first belief axis are more likely to have a positive attitude toward dissection.

The sixth belief is that *touching, seeing, or smelling the dead body of an animal is not offensive enough to negatively impact students' learnin*g. Student beliefs fell into three categories: 1) dissection is unclean or dirty; 2) dissection smells bad; and 3) dissection is "gross." Students who are less inclined to agree with these attitudes are more likely to have a positive attitude towards dissection. On the survey, 39% of the students were in agreement with the statement, "I think of dissection as being unclean or dirty," and 85% of the students were in agreement with the statement, "I don't like the smell associated with dissection." Comments of this nature were by far the most commonly heard in the classroom.

Finally, the seventh belief, *dissection as an activity is independent of the experiences the students are familiar with, and how they interpret those experiences*. Related student beliefs fell into three categories: 1) positive or neutral everyday experiences with dissection-like activities; 2) negative everyday experiences with dissection-like activities and; 3) other familiar experiences relevant to the perception of dissection (for the purposes of this study, "dissection-like" activities are those that involve the inside of an animal, such as hunting/cleaning animals, surgery, preparation of meat, etc.). Students agreeing with the first category were strongly inclined to have a positive attitude toward dissection, while those agreeing with the second category were strongly inclined to have a negative attitude toward dissection. Sets of values characterize each of the six beliefs inherent in the activity of dissection. These values may be negatively worded, as in "suffering should not be tolerated," or positively worded, as in "courage is an admirable quality," depending on the context in which they emerged. These value sets are described in Appendix B.

Conclusions

In this research study I have attempted to construct a model of the meaning students assign to the dissection experience through a comprehensive exploration of the issues most prevalent in students' minds as they relate their thoughts and feelings about the issue. Conclusions are addressed with the research questions as organizers.

1. What major factors in the life experiences of the students (gender, religion, past experience) contribute to the development of their value systems related to the dissection experience?

Students related various life experiences that were instrumental in shaping their perceptions of dissection. These familiar experiences are woven throughout the data as students related stories of their home life and upbringing. Examples of these experiences were: hunting; fishing; working with and/or killing domesticated food animals; religious teaching; parental teaching; taxidermy; and pregnancy. In the findings of the study, these experiences emerge as strong influences on students' perceptions of dissection. In a related study, Crowell, Smith, Oliver, Simpson, & Adams (1987) explored the influence of veterinary students' life experiences on their attitudes towards animal use. Conclusions of the study revealed that students from rural areas were more likely to have liberal attitudes towards the use of animals. This finding suggests that unlike students from urban areas, students living in rural areas are more likely to be familiar with using animals in their everyday life. As these students are familiar with behaviors associated with animal use, they should, therefore, hold more positive attitudes towards those behaviors. In general, this finding suggests that individuals have a tendency to develop positive attitudes towards familiar life experiences.

Applying this assumption to the context of dissection suggests that students whose home life includes dissection-like activities, such as hunting, fishing, or killing chickens, should be more likely to have a positive attitude towards dissection. However, this assumption is contradicted in the findings of the study. The life experiences that were familiar to the students were not always positively interpreted, in fact, many times "the familiar" took on a very negative meaning. For various students, very similar life experiences might take on either positive or negative meaning. Consequently, the influence of familiar life experiences on student perceptions lies in the interpretation and meaning constructed by the individual student.

An example of the highly variable influence of the "familiar," religious teachings emerged as a factor contributing to students' perception of the killing of animals. However, according to the findings of the study, religious beliefs in themselves cannot be assumed to shape perception of dissection in a positive or negative direction. The influence of religious teachings on students' perception is dependent on individual interpretation. This was illustrated as students cited their religious beliefs in narrations of both negative and positive attitudes towards the killing of animals (Certain students who expressed deep religious beliefs negatively interpreted dissection because they felt it was disrespectful to God's creation, while others positively interpreted dissection because they felt God put animals here for our use). The responses suggested that assumptions or general statements can not be made concerning the effects of religious beliefs on perceptions of dissection.

Experiences with hunting also highlight the significance of students' interpretations of familiar phenomena. Regardless if the student was male or female, actively or passively involved, familiarity with hunting was interpreted in variety of ways. This pattern also emerged in students' narrations of killing domesticated animals for food, fishing, and parental teachings.

On several occasions, students related familiar experiences that were indirectly or abstractly associated with dissection, but were nevertheless important in shaping their perception of dissection. These experiences deviated somewhat from the more stereotypical dissection-like activities (hunting and fishing, etc.) and involved topics such as pregnancy and illness of a loved one. These abstract and obscure influences on student's perceptions emphasizes the complex nature of the influence of life experiences on students' construction of meaning.

2. How do the students' personal values compare and contrast with those found in the secondary science curriculum?

Goodenough (1963) wrote of the relationship between people's values and the community to which they belong. He maintained that for any given community or social class, there will be some value orientations that are common to the personal sentiments of virtually everyone in it. He goes on to say that small, unstratified communities tend to have a broader base of common sentiments than do large and socially complicated ones. According to Goodenough's premise (1963), a comparison of the two value systems discussed in this study should reveal that the scientific community, a smaller, less stratified group than the students in the study, possesses a much more consistent, unified, and consolidated set of values.

Simpson, Koballa, Oliver, & Crawley (1994) identified several values they considered relevant to scientific inquiry. These are: 1) longing to know and understand; 2) questioning of all things; 3) search for data and their meaning; 4) demand for verification; 5) respect for logic and; 6) consideration of the consequence. A comparison of this list of six values relative to the widely variable list of 39 values students related during their discussions of dissection supports Goodenough's premise. The values associated with scientific inquiry are much more consistent, unified, and consolidated than the students' personal values relevant to the activity of dissection.

Of the six values listed by Simpson, Koballa, Oliver, and Crawley (1994), three also emerge as students related their thoughts on the epistemological issues embedded in dissection. While the values considered relevant to scientific inquiry are centered around cognitive and epistemological considerations, the large number of student values reflected in the study move beyond the boundaries of these issues. Although scientific inquiry is described as a value-laden human endeavor (Lederman, 1992) value constructs such as kindness, respect for authority, love, excitement, aggression, and suffering are absent from its description. Comparing and contrasting these sets of values marks a wide division between student and scientific values.

Implications

Heated debate surrounds the issue of whether or not dissection should be used in the high school biology classroom. Participants in debates rhetorically champion one viewpoint or the other, addressing the reasons why dissection should or should not be used in the classroom. Proponents of dissection argue that it grounds scientific understanding of animal anatomy in empirical evidence-that students need to see and feel it for themselves in order to learn. Opponents of dissection center their arguments on biology as the study of living organisms and their interactions, and that dissection teaches students a disrespect for life. Unfortunately, in the end these types of discussions offer little help for teachers and teacher educators who speculate over the usefulness of dissection as an instructional tool. Dissection is perceived as a wonderful learning tool by some students while it acts to alienate others from learning. In providing an analysis of how individuals perceive dissection along with an exploration of the underlying values and beliefs that shape those perceptions, this research provides novel insight into the dissection experience.

The moral values forming the organizational core of the study are deeply held by the participants, and when violated can sometimes cause a great deal of emotional discomfort for students. Moreover, it is suggested that the issues of religious beliefs, death and suffering, and humans' place in nature, which saturate the students' narrations, are of paramount importance relative to all other moral issues. Educators who maintain dissection is the "only" way to learn about animal anatomy are disregarding the value-oriented nature of their students. Imposing the moral values of others on students and expecting they act and feel in a manner conducive to learning is unrealistic. It is unlikely that students whose moral values are at odds with those inherent in dissection will have a positive learning experience with the activity. For these students, alternatives to dissection provide a vehicle through which they can comfortably learn about animal anatomy.

In spite of the tendency to minimize the importance of dissection's physical dimension, physical aversion was found to impinge on students' learning from dissection. Comments concerning physical aversion were by far the most commonly heard in the classroom, while comments about learning were some of the least common.

Many educators who choose not to use dissection in their classrooms argue that the understanding students gain from dissecting an animal is minimal. While it was beyond the scope of this study to quantitatively evaluate the effect of dissection on students' learning, many students did have positive attitudes about learning from dissection. For these students, whose value systems are consistent with those in dissection, the activity seems to build upon a natural curiosity about their own bodies. This curiosity, coupled with the excitement some students experience during dissection, increases its potential as a very motivational learning tool.

Findings suggest that the students found the frog, turtle, and shark dissections the most interesting and informative, and the earthworms, perch, and grasshoppers the least informative.

Some students also found the fetal pigs to be useful and informative. However, so many of the negative feelings in the study centered around dissecting the fetal pigs, that the decision to use them should be weighed carefully.

The students involved in this study have given new insight into the long-fought debate over the use of dissection in the high school biology classroom. Ultimately, the responsibility of the decision to use or not to use dissection falls to the high school teacher. We hope that teachers and teacher educators alike can use the information in this study to make more informed decisions about the use of dissection in the high school biology classroom.

Appendix A

Period: ________

First Name: ____________________

After reading each statement, please indicate the extent to which you agree or disagree, by circling the number to the right of each statement. There are no correct or incorrect responses. NOTE: If a statement does not apply or if it never occurred to you, circle "U."

SA = Strongly Agree
A = Agree
U = Undecided (or doesn't apply)
D = Disagree
SD = Strongly Disagree

1. It can be exciting to kill animals for food (like deer).	SA	A	U	D	SD
2. I feel okay if an animal has been killed for me to use, but I would not actually kill it myself.	SA	A	U	D	SD
3. I feel okay if an animal is killed, as long as it is for a good reason.	SA	A	U	D	SD
4. I am opposed to killing animals.	SA	A	U	D	SD
5. Dissecting fetal pigs is better than dissecting other animals because they were never alive in the first place.	SA	A	U	D	SD
6. Dissecting fetal pigs is worse than dissecting other animals because they never got a chance to live.	SA	A	U	D	SD
7. Sometimes dissection is difficult for me because the way I was raised, you're just not *supposed* to be cutting open dead animals.	SA	A	U	D	SD
8. Dissection is exciting because we get to do something that we aren't "supposed" to do.	SA	A	U	D	SD

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9. Sometimes when I'm cutting, probing, or pinning during a dissection, I think about it being done to my own body.	SA	A	U	D	SD
10. Sometimes when I'm cutting, probing, or pinning during a dissection, I think about it being done to my pet's body.	SA	A	U	D	SD
11. Sometimes when I have looked at the dead animal in the dissecting pan, I have thought about how my body will be when I'm dead.	SA	A	U	D	SD
12. I don't like the smell associated with dissection.	SA	A	U	D	SD
13. Seeing blood is really gross.	SA	A	U	D	SD
14. I am curious about exploring the inside of an animal.	SA	A	U	D	SD
15. I think of dissection as being unclean or dirty.	SA	A	U	D	SD
16. The fact that dissection is unclean makes it more exciting.	SA	A	U	D	SD
17. As an animal's body more closely resembles the human body, dissection becomes more exciting.	SA	A	U	D	SD
18. As an animal's body more closely resembles the human body, I feel like I learn more.	SA	A	U	D	SD
19. As an animal's body more closely resembles the human body, dissection becomes more disturbing.	SA	A	U	D	SD

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20. For me, dissecting the head of an animal is more disturbing than the rest of the body.	SA	A	U	D	[illegible]
21. When I dissect the head of an animal, I sometimes think about that being done to me.	SA	A	U	D	SD
22. Dissecting the head of an animal is exciting because the structures are the most important on the body.	SA	A	U	D	SD
23. Dissecting the head of an animal is fun because it's so gross.	SA	A	U	D	SD
24. Taking an active part in the dissection helps me to do better on the test.	SA	A	U	D	SD
25. Grades are important to me.	SA	A	U	D	SD
26. I feel better about dissection if I know the animal was raised specifically for dissection.	SA	A	U	D	SD
27. During dissection, I feel like I'm being disrespectful to the animal.	SA	A	U	D	SD
28. Sometimes during dissection, I feel like I'm hurting the animal.	SA	A	U	D	SD
29. I consider myself a religious person.	SA	A	U	D	SD
30. I have a close relationship with my pet(s). ("U" if you don't have pets)	SA	A	U	D	SD

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31. It's okay to kill animals for dissection because we learn from it. SA A U D SD

32. Most girls don't like dissection. SA A U D SD

33. It can be exciting to kill animals that are dangerous (like snakes). SA A U D SD

34. During my lifetime, I have had the opportunity to see things that were similar to dissection (cleaning fish, deer, etc.):

_____ Always

_____ Frequently

_____ Sometimes

_____ Seldom

_____ Never

35. If you did have the opportunity to see these activities, were you:

_____ Extremely interested

_____ Very interested

_____ Somewhat interested

_____ Not interested at all

31. If you are interested or curious about the insides of animals, what is it that you want to know? ____

____

Appendix B

I. Moral Issues:

Values Inherent in the Killing of Animals	
preservation of self	preservation of environment
aggressive behavior	skill
endangerment of self and others	suffering
compassion	protection of self and others
nurturing	love
courage	kindness
sanctity of animal life	human need

Values Inherent in the Acceptable Treatment of the Dead	
respect for the dead	acceptance of peers
compassion	sanctity of life
moral consideration	kindness

Values Inherent in Cultural Taboo	
respect for authority	curiosity
rebellion	forbidden knowledge
respect for the dead	unknown

Values Inherent in Thoughts about Self	
sanctity of own life	suffering
curiosity	sanctity of own body

knowledge	

II. Values Inherent in Epistemological Issues:

empirical grounding	knowledge/learning
investigation/discovery	intellectual independence
curiosity	physical interaction

III. Values Inherent in the Familiar:

human need	work
death as part of life	compassion
learning/knowledge	sanctity of animal life
love	excitement
cleanliness	

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INFLUENCE OF AN EXTENDED ELEMENTARY SCIENCE TEACHING PRACTICUM EXPERIENCE UPON PRESERVICE ELEMENTARY TEACHERS' SCIENCE SELF-EFFICACY

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Introduction

Science self-efficacy repeatedly has been identified as an influential construct in science teaching (Riggs, 1988; Enochs & Riggs, 1990; Vinson, 1995; Cole, 1995; Wilson, 1996). Bandura (1977) was one of the first to suggest that one's abilities were mediated by individual expectations of personal efficacy, or self-efficacy. Self-efficacy, or increasing the extent to which teachers believe they can influence student learning, is an important attribute in effective science teaching (Enochs & Riggs, 1990; Ramey-Gassert, 1993; Enochs, Scharmann, & Riggs, 1995;). Self-efficacy can be influenced by a variety of factors, e.g., gender, content area, and professional standing (inservice vs. preservice). Preservice teachers, then, ideally should possess a high degree of self-efficacy involving the teaching of science in order for their students to be positively influenced about learning science.

Practicum experiences in colleges or schools of education were defined for this research as a course of study designed especially for the preparation of teachers and clinicians that involves the supervised practical applications(as in classroom or clinic) of previously studied theory. Practica experiences such as these have oft resided within the course requirements of teacher preparation programs.

For example, The University of Montana, Missoula, Montana, 22 years ago required of education majors EDUC 200, *Orientation to Education*. The major component of EDUC 200 was field work, teaching lessons in content areas, such as math, science, or reading, at one of the local schools.

Practica, or field experiences, are not the clarion call that many staunch educational reformists of the past decade have been demanding. Goodlad(1990) comments of the need for teacher educators to realize the likely discrepancy between the ideals of the methods course and the reality of the classroom.

Indeed, educational reform zealots note that practicum experiences can be traced back to the era of the one room school house where older children were teaching the little children.

The variety of practica (or field/laboratory/clinical) experiences for preservice teachers continue to be diverse. With the expansion of the World Wide Web, and the Internet, more and more colleges and universities are rushing to post their school's professional programs and course requirements on institutional Websites or homepages. In less than one hour, one can surf through the many such Web sites maintained by both large and small colleges and universities and can clearly see this diversity in practice. For example, the Penn State College of Education homepage (*http://www.ed.psu.edu.dept/cert/student_services/field_exp.html*) notes that "all teacher certification programs have pre-student teaching field experiences as part of their curriculum" (line 6). No less than eight courses fulfill this requirement, which range from students spending 5 days in an elementary school to be followed by five days in a high school to "a three credit practicum taken concurrently with methods courses from the. . .areas of math, science, and social studies education" (lines 22-23). Penn State education students are in the schools for approximately one and a half days per week and participate in a seminar. The state of Kentucky, through their Kentucky Education Reform Act (KERA) enacted in 1990, requires that "each student must spend a total of 150 hours in field experiences and laboratory experiences prior to student teaching" and that "at least 75 hours of the 150 hour total must be in field experiences in the schools" (Centre University, *http://centre.edu/academic/programs/edu/handbook/!field.htm*, lines 2-4).

Kent State University requires "300 clock hours of field/clinical experiences before [students] are able to teach" (Kent State University, available via the World Wide Web at *http://monster.educ.kent.edu/CoE/Offices.PDP/early.htm*). The University of Iowa also requires "a minimum of 50 clock hours of practicum to fulfill minimum Iowa licensure requirements" (University of Iowa, *http://www.uiowa.edu/~coe2/entities/studserv/field-experience.htm*, lines 27-28). Practica experiences are not just for major universities. Saint Mary's University in Winona, Minnesota, requires courses in which "field experiences are required" (http://www.mnsmc.edu).

Farris, Henniger, and Bischoff (1991) reviewed the current state of practicum experiences. In a study of 217 of the largest teacher education programs of public colleges and universities, the perceived diversity in practica experiences was grounded in reality. They found that field experiences for education students varied from spending 5.20 hours per week in schools over a seven week period to two full days a week in attendance. Surprisingly, they also report that "supervision of the early clinical [e.g. practicum] experiences ranged from no on-site visits by the university supervisor to a high of four or more visits for the first experience" and that "15.2% [out of 175 responding institutions] require supervision by university personnel for second and third year experiences (p. 23).

The Problem and Purpose

This albeit short, but telling, review of practica experience literature reveals that education majors appear to be out in the schools, but as to for how long, under whose supervision, and exactly what the requirements of the education majors are in these experiences is as diverse as there are institutions of higher learning and states of the union. There seems to be no even imprecise measurement as to exactly "how much" or "how many" practica experiences should be required for the preservice education majors. With more and more responsibilities being placed on university faculty resources, the issues of "how much" and "how many" experiences become even more significant. Therefore, the purpose of this study was to compare two early field(practica) experiences of two different land grant universities; one in the midwest, one in the west. The midwestern university students taught one science lesson in an elementary school as their practicum experience. The western university students taught elementary science for an entire semester for their practicum experience. The data from the study are preservice elementary teachers' personal science teaching efficacy scores (PSTEB) from the Science Teaching Efficacy Beliefs Inventory (STEBI version B) by Enochs and Riggs (1990) from both universities.

Research Questions and Hypotheses To Be Tested

There were three research questions to be tested:

1. Does an extended science teaching practicum experience positively influence a preservice teacher's personal science teaching efficacy beliefs?
2. Is science self-efficacy influenced by the length of the teaching practicum?

3. Does taking an elementary science methods course along with the practicum experience influence science self-efficacy?

The corresponding hypotheses were as follows:

1. There is no significant variance between the PSTEB scores of differing practica experiences(single, one time experience vs. extended, 10 week practica).

2. There is no significant variance between the PSTEB scores of differing practica experiences(single, one time experience vs. extended, 10 week practica).

3. There is no significant variance of PSTEB scores of the western university's preservice teachers' who have previously taken an elementary methods course and those western university's preservice teachers who have never taken an elementary science methods course.

Method

Subjects

Subjects included 64 preservice elementary education majors. Forty-six students were from a large midwestern university (41 females and 5 males) and 18 (14 females and 4 males) were from a land grant university in the west. The subjects level of academic preparation varied by institution.

The students from the midwestern university were in their final semester before student teaching and were enrolled in a 3 semester credit elementary science methods class which required a single, one time only science teaching practicum experience. The students from the western university were enrolled in a 3 semester credit *Supervised Elementary Education Practicum* course open to juniors, seniors, and graduate students. The teacher preparation program of the western university included Masters degree, first time licensure graduate students in the practicum course. None of the preservice teachers taking the practicum course were concurrently enrolled in an elementary science methods course. Both groups of students were determined as being from the same population (elementary education majors) based upon the lack of statistically significant differences of their Preprofessional Skills Tests scores in reading($t = -1.78, p = .10$), writing($t = 9.36$, $p = .92$), and mathematics($t = -1.63, p = .11$).

Instrumentation

The STEBI B (preservice version) (Enochs & Riggs, 1990) was administered to both groups of preservice elementary teachers. The STEBI B includes 23 Likert-scaled statements relating to personal beliefs about teaching science. Response categories are "strongly agree," "agree," "uncertain," "disagree," and "strongly disagree." The STEBI B measures two sub-scales inhering to Bandura's (1977) theory of self-efficacy and applied to teaching by Gibson and Dembo (1984). The two subscales are personal science teaching efficacy beliefs (PSTEB) and science teaching outcome expectancy(STOE). The sub-scale for PSTEB numbers 13 statements. A full account of the reliability and validity measures for STEBI B can be found in Enochs and Riggs (1990). This study resulted in a Cronbach's alpha of .83 for the PSTEB and .77 for the STOE.

The administration of the STEBI B occurred at roughly the same time for both groups. The midwestern group completed the STEBI B after teaching one science lesson in a public school. This lesson was taught near the end of the university semester. The lessons lasted approximately 1 and a half to 2 hours in length.

The western preservice teachers completed the STEBI B after an extended practicum experience in a local public school. The practicum experience ran from 8:00 a.m. to 12:00 noon on Tuesdays, Wednesdays, and Thursdays, for 10 weeks, totaling 120 hours of pupil contact time. Although the primary responsibility of the preservice elementary students in the practicum was to teach science lessons from the adopted public school science curriculum, they also were responsible for daily management routines and any other planned content area lessons with the permission of the cooperating classroom teacher.

Analysis

A modified quasi-experimental pretest-posttest design with nonequivalent groups was used in this research. PSTEB data obtained from the midwestern university was compared to PSTEB data collected from the western university. The independent variable was the different university preservice elementary teacher groups(midwestern and western). The dependent variable was the PSTEB scores from the STEBI B for both groups. The experimental group was the western university's preservice teachers. The experimental treatment was the length of the practicum experiences(10 week long practicum experience as compared to a single 1 and a half to 2 hour practicum experience). The control group was the midwestern university preservice elementary teachers. Due to the small sample size and ordinal nature of the STEBI B data, nonparametric analyses were deemed appropriate.

Results and Discussion

Mann-Whitney U tests were performed on both pre and posttest PSTEB scores from both university's preservice teachers. No significant differences were found in the pretest PSTEB scores between the midwestern and western preservice elementary teachers as seen in Table 1.

Table 1

PSTEB Pretest Scores of Midwestern and Western University Preservice Teachers

Before a Practicum Experience

Group	N	Sum of the Ranks	Z	p
Midwestern*	46	533.5	.38	.70
Western**	18			

* median PSTEB score = 54

** median PSTEB score = 56

Research Question One

The first research question, "Does an extended science teaching practicum experience positively influence a preservice teacher's personal science teaching efficacy beliefs?", was found to be true. The Mann-Whitney U test results indicate that an extended practicum experience does positively influence a preservice teacher's personal science teaching efficacy beliefs when compared to a single, one time only practica experience (see Table 2).

Research Question Two

The Mann-Whitney U test results for the second research question, "Is science self-efficacy influenced by the length of the teaching practicum?", suggest that the length of a practicum experience does influence a preservice teacher's personal science teaching efficacy beliefs (see Table 2). In addition, the median PSTEB posttest score of the midwestern preservice teachers' group was 56 as compared to the western preservice teachers' group PSTEB median score of 60.

Table 2

PSTEB Posttest Scores of Midwestern and Western University Preservice Teachers
After a Practicum Experience

Group	N	Sum of the Ranks	Z	p
Midwestern*	46	1363.5	-1.96	.04
Western**	18			

* denotes group with a single, one time only practica experience 1 and a half to 2 hours in length; median score = 56

** denotes group with a 94 hour requirement of elementary science teaching practica experiences; median score = 60

Research Question Three

The third research question, "Does taking an elementary science methods course along with the practicum experience influence science self-efficacy?", was found to be false. An Analysis of Variance of PSTEB posttest scores reveal no significant difference in variance between the western university preservice teachers groups(methods vs. no methods) . This result suggests that previous enrollment in an elementary methods course has little influence on preservice teacher's personal science teaching efficacy beliefs (see Table 3).

Table 3

Analysis of Variance of PSTEB Posttest Scores of the Western University Preservice Teachers

Source	DF	Sum-Squares	Mean Square	F-Ratio	Prob>F	Error Term
A (METHODS)	1	40.5	40.5	2.74	0.1173	ERROR
ERROR	16	236.44	14.77778			
TOTAL(Adj)	17	276.9445				

A sign of valuable research is when more questions are raised from a project than were originally asked. This research study did exactly that.

Based upon the review of self-efficacy research, one could safely predict that an extended practica experience would positively influence PSTEB scores more so than a shorter practica experience. Many have suggested that experience *is* the best teacher. What is interesting about this prediction is determining when, if ever, a point of diminishing return exists in field work or practica experiences.

The midwestern university preservice teachers' mean PSTEB posttest score was 56.28 (model response = 65) as compared to the western university's mean PSTEB posttest score of 58.94 (mr = 65). A difference of roughly 3 points demonstrated statistical variance. Effect size was calculated to be .57 (reject practical significance if < .33) (Borg, Gall & Gall, 1993). Borg, Gall, and Gall (1993) state that "an effect size of 1.00 is twice as large as effect size of .50. The mean of the effect sizes...can be calculated to yield an estimate of the effect of the experimental program or method... "(p. 171). Therefore, according to Borg et al. (1993) one could argue that the effect of the extended practicum was roughly twice as "effective" as the single, one time only practicum experience.

What is the most ideal amount of practica experiences? The results of this study *could be* interpreted that preservice elementary science teachers who experience an increase from approximately 2 hours of practicum pupil contact time, teaching a single lesson in elementary science, to approximately 94 hours(adjusted from 120 hours for daily routine activities) of pupil contact science teaching time gain "twice" the effect of teaching experience from such an increase in hours. This conjecture, despite what the numbers report, cannot be validated based on PSTEB scores.

But, yet another very important question arises. If the question raised above is reversed, could one argue for *less time* to be spent in elementary science teaching practica experiences? It appears that only 3 to 4 out of 65 total PSTEB points are gained toward "ideal" science teaching efficacy by increasing supervised practicum experience pupil contact teaching time by a factor of roughly 6. Does this result support the call for increased practicum experiences and time spent supervising such experiences by already overburdened university content area specialists? Perhaps, but this author strongly suggests that "a point of diminishing return" someday will be determined through an expanded research agenda relating to science self-efficacy and practica experiences.

What is the most ideal (or effective) PSTEB score? The model response of 65 would be an appropriate answer. However, if one scores 56.28, does this mean they are only 86% of an science efficacious teacher? Is 86% of an efficacious elementary science teacher acceptable? To editorialize, this author gladly would place an 86% science efficacious elementary teacher in a classroom based upon observations of how dismal, if at all, elementary science is being taught in the public schools.

Two surprising corollaries were the lack of influence of gender (N = 18, f = .01, *df* = 1, *p* = .91) and enrollment in an elementary science methods course(N = 18, f = 2.74, *df* = 1, *p* = .11) on the posttest PSTEB scores in the western university's practicum experience. Gender data were not asked for at the midwestern university.

The western university's preservice elementary teachers, not previously enrolled in an elementary science methods course, did receive a "crash course" in elementary science teaching before entering the public school classroom. This instruction amounted to 9 hours of class time. Taken at face value, this result suggests that an elementary science methods course is not a prerequisite for developing a highly science efficacious elementary teacher. All students at the midwestern university were enrolled in an elementary science methods course which required a single, one time only science teaching practicum experience.

Conclusions

To conclude, this research, however small in sample size, indicates that extended practicum experiences in elementary science teaching positively increases a preservice elementary science teacher's personal science teaching efficacy beliefs. Departures for further research include 1) determining exactly where a preservice elementary teacher's PSTEB matures and remains stable, 2) exactly what type of experience(s) and how much pupil contact time is required for this PSTEB maturation and stabilization process to occur, and 3) locating or developing other sister-like STEBI B instruments that could be used in time series experimental designs to reduce the potential of the research subjects developing test sensitivity to one instrument being administered many times. All of the above are currently underway at the University of Nevada, Reno.

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THE HEALTH SCIENCES AND TECHNOLOGY ACADEMY: PROFESSIONAL DEVELOPMENT FOR SECONDARY SCIENCE TEACHERS THROUGH A COMMUNITY-BASED CURRICULUM ENRICHMENT PROGRAM FOR UNDERREPRESENTED STUDENTS

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The Health Sciences and Technology Academy

The Health Science and Technology Academy (HSTA) is a partnership between West Virginia University (WVU) and communities (many rural Appalachian) in West Virginia, and is funded by several sources, including the W. K. Kellogg Foundation, Howard Hughes Medical Institute, and Dwight Eisenhower Science and Mathematics Act. HSTA is part of a "pipeline" of educational support programs offered through WVU to help financially disadvantaged and minority students interested in health science careers (e.g., pharmacy, medicine, nursing, dentistry) to realize their goals and insure that West Virginia's future need for health care providers is met (Bock, 1996). As such, HSTA is administered through the Robert C. Byrd Health Sciences Center at WVU, but also involves university faculty from the natural sciences, education, mathematics, and other disciplines. HSTA programming is provided through on-campus (WVU) summer institutes and, more extensively, through extracurricular "after school" science (HSTA) clubs in West Virginia communities. It targets most directly financially disadvantaged and African-American students (hereafter referred to as underrepresented students), grades 8 through 12. The program was launched with 45 students from two counties in 1994. Currently, about 200 students--over 60% female and 40% minority (mostly African-American)--from 11 West Virginia counties participate in HSTA, and funding is being sought for program expansion.

The long range goal of HSTA is to increase the number of underrepresented students who complete a post-secondary education in the health sciences and remain in West Virginia as primary care givers. This goal responds to the need to bolster the college-going rate amongst underrepresented students and the number of health care practitioners in medically underserved and rural Appalachian West Virginia communities. The more immediate goals pertain directly to the multifaceted academic enrichment provided through HSTA, and are to increase the following in underrepresented students: (a) competence in science and mathematics, (b) technological literacy, (c) capability for leadership, (d) interest in pursuing postsecondary education in the health sciences, (e) study skills, (f) self-esteem and (g) allegiance to rural West Virginia communities. These goals respond to the need to provide equitable access to learning opportunities for underrepresented students, and specifically to foster higher levels of scientific literacy "for those who traditionally have not received encouragement to pursue science--women and girls, students of color . . ." (National Research Council, 1996, p. 221).

Twenty-six secondary science and math teachers also participate in HSTA, and are the most important "learning resource" in the provision of academic enrichment to HSTA students (National Research Council, 1996). Accordingly, a critical thrust of HSTA is teacher professional development, and they have the opportunity to earn graduate credit leading to a Master's degree in secondary science education through their role and responsibilities as a HSTA teacher-participant. Teachers collaborate with post-secondary faculty in the natural and health sciences, education, and mathematics to provide HSTA students with on-campus learning experiences at the HSTA Summer Institutes. These learning experiences have ranged from study skill development (e.g., concept mapping) to research projects in the areas of forensic science and neuroanatomy to constructing World Wide Web sites (see <http://www.ana.wvu.edu/hsta>). Teachers learn about instructional strategies and resources for making successful community-based HSTA programming. The community-based programming extends this collaboration as teachers facilitate extracurricular HSTA club experiences for students, and network with community resources such as health care providers/facilities and professionals employed in areas related to environmental quality. These experiences include the development and conduct by students of extended investigations, where they make inquiry into problems that have relevance to health and local communities, and develop understandings about research and skills in collaboration and communication.

Related to the learning of science through inquiry, the National Science Education Standards (National Research Council, 1996) describe the critical need for a paradigm shift from teacher-directed to student-centered instruction, where teachers become facilitators of learning. An important anticipated outcome of the professional development provided by HSTA is this paradigm shift amongst teachers, and the transfer of what they learn and do in HSTA to their regular science classroom. In their article describing a professional development model that includes after school math, science, and technology clubs for elementary students, Shroyer, Ramey-Gassert, Hancock, Moore, and Walker (1995) contend that "professional development of teachers may well be one of the most critical aspects of the science education reform movement" (p. 112).

Lieberman (1995) reports there is growing evidence that partnerships, such as HSTA, can be "powerful organizational arrangements" for teacher professional development, where teachers can "commit themselves to topics that are of intrinsic interest to them" and which "provide access to new ideas and a supportive community in which to begin translating these ideas into meaningful action in schools and classrooms" (p. 595). The majority of teacher professional development through HSTA programming takes place in the context of the extracurricular HSTA clubs, where teachers learn by doing and reflecting on their actions (Bullough & Gitlin, 1991), and where emphasis is placed on "teacher as source and facilitator of change" and "member of a collegial professional community" (National Research Council, 1996, p. 72). The remainder of this paper will describe the extracurricular HSTA clubs, relate HSTA club programming to teacher professional development (including specific graduate course assignments), and report teacher-participants' evaluation of such programming and a related graduate course.

Extracurricular HSTA Clubs

A major thrust of HSTA is to establish "working" extracurricular science (HSTA) clubs that emphasize inquiry-based science and provide exposure to careers in the health sciences, and utilize community and higher education resources in doing so. As such, these HSTA clubs extend the school science program beyond the "walls" of the classroom for the student participants. Before describing these clubs in more detail, it is critical to acknowledge the tremendous challenge of engaging underrepresented students in science and math academic enrichment after a full day of school. Shroyer et al., (1995) reported that such after school programming for elementary level students needed to be fun, with the principal theme of problem solving in order to relate science and math to students' future lives. Such likely are even more critical at the secondary level, where HSTA club programming competes with several "after school" opportunities. On the other hand, programs like HSTA fill an important gap in extracurricular offerings, as described by one HSTA teacher in a graduate course assignment that solicited teachers' perceptions about what students were gaining from HSTA club experiences:

> They [some students] need to be associated with a club that makes them feel worthwhile and valuable and smart and important. These kids that show those needs make me feel valuable. . . .Today's schools leave out a large percentage of their students as far as extracurricular activities are concerned. Athletic or outgoing students are rewarded and placed into higher positions on the social ladder--shy, introverted, serious, and mature students are stigmatized and not allowed certain outlets. For some of my HSTA students, I see their pleasure in being involved and feeling important.

Eighteen HSTA clubs are operational in the 11 counties targeted by HSTA. Each club is facilitated by 1 to 2 teachers, and an attempt is made to keep the teacher to student ratio to 1:10. Clubs meet from two to four times per month, usually after school (and sometimes on Saturdays) at the HSTA teachers' schools. To facilitate community commitment to HSTA club programming, six regional Local Governing Boards have been established (the number of clubs "governed" by each board ranges from 1 to several). Board membership includes representation from parents of HSTA students, HSTA students, local schools, local health care facilities, and others in the communities. Boards are charged with providing guidance and decision-making in the areas of personnel, budget, curriculum and learning resources, and student recruitment and retention. A WVU faculty member in curriculum and instruction who has a health and science education background serves as the curriculum coordinator to teachers who facilitate the HSTA clubs. Teachers receive additional support and guidance from a HSTA program manager at WVU and six regional HSTA field site coordinators. These field site coordinators are a critical link between the community and WVU, and carry out vital roles in student recruitment and retention and identification of community resources for HSTA club programming. The field site coordinators are especially important in identifying opportunities for students to gain exposures to health care careers. In reference to the latter, a valuable resource to the field site coordinators are the clinics and learning resource centers of the West Virginia Rural Health Education Partnerships (WVRHEP) located throughout West Virginia. WVRHEP is a program of the University System of West Virginia and provides clinical training opportunities at rural health clinics and small rural hospitals around the state.

The 4-H model (Division of Family & 4-H Youth Development, 1992) was adapted in setting forth organizational principals and group dynamics and providing a structure for HSTA club meetings. A model (yet flexible) agenda outline was provided for teachers to utilize in order to get the HSTA clubs "up and running: " (a) begin the meeting with a brief inquiry/discovery activity (e.g., Liem, 1987) to engage students; (b) devote a significant amount of meeting time to utilizing the problem posing, problem solving, and peer persuasion (the "3Ps") instructional model (Peterson & Jungck, 1988), in order to help students develop and carry out extended investigations, i.e., collaborative science projects; and (c) include in some meetings a presentation on a health career by a local health professional. Parental involvement in the meetings and student activity outside of the meetings also are emphasized. In regards to the latter, student activities have included shadowing local health care providers, volunteering at health care facilities and assisting with area health fairs and screenings (which also provide important community service), collecting data as part of extended science investigations, and taking field trips to higher education and government facilities.

Contributing to the development of INTERNET literacy amongst students also is a goal of HSTA club programming. Through the Bell Atlantic World School Program, many of the schools where HSTA clubs meet have a direct connection to the INTERNET. Students conduct INTERNET searches to learn more about specific problems targeted by their extended investigations. It is anticipated that future uses of the INTERNET by HSTA students will include posting data on collaborative science projects (e.g., water and air quality), video conferencing with other science clubs and university faculty, and establishing and maintaining HSTA club Web sites that will, amongst other features, showcase their extended investigations.

As mentioned above, these extended investigations (i.e., science projects) are a principal thrust of HSTA club programming. Ideally, they arise from student brainstorming sessions about problems that exist in their own communities that have some connection to health. It is critical that students play a primary role in identifying the problems. Student interest is paramount to HSTA club attendance and all phases of the investigation, which includes proposal development, conducting the investigation, and developing and providing related poster and oral presentations at an annual HSTA science fair. During the 1995-96 school year, approximately 30 different investigations were carried out and presented at the HSTA 2nd Annual Science Fair. Each project usually was completed and presented by small groups as opposed individual students, in order to nurture collaboration and a "community of learners." Sample project titles as listed in the science fair brochure are shown in Table 1.

Table 1
Samples of Extended Investigations Presented by Students at the HSTA 2nd Annual Science Fair

Testing ground water in Webster County.
Weyerhaeuser run-off evaluation of Salt Lick Creek.
Does the type of bedrock affect chemical & benthic macroinvertebrate composition of streams?
Lead? pH? A water analysis of three Kanawha schools.
Survey of chlorine, manganese, and iron in the Coalwood and surrounding water systems.
Acid rain in Ohio county.
Calorie amount of heat values of nuts.
Amount of moisture in fat and meat.
Contrasting percent of calories from fat in male and female diets of HSTA students.
Effect of nicotine on mealworms.

Many of the projects completed by students during the 1995-96 school year targeted water quality. Water quality is a major concern in West Virginia, which has over 92,000 streams inventoried to date (Mains, 1993). Water quality has been negatively affected by acid mine drainage and other pollutants, and this impacts recreational opportunities in and the economy of the state. The project that posed a question about the affect of rock type on the benthic population and chemical composition of water was a collaboration between two HSTA clubs in different portions of a county. The project examined two streams, one which had been treated for acid mine drainage and another which ran through a "resort" golf course. The Weyerhaeuser project was an evaluation of the impact of construction of an oriented strand board industry on various chemical (e.g., phosphates and chlorine) and biological (e.g., benthic macroinvertebrates) parameters of a local stream. The project offered a robust learning experience through collaborating with private industry and a government agency (Rye, Burchett, McMillion, & Howell, 1996), and students are continuing this investigation during the 1996-97 school year by examining for any effect that industrial production of strand board has on the stream. Another investigation undertaken in 1996-97 by three HSTA clubs in three different counties targets emissions of nitrogen oxides (specifically NO and NO_2) in and surrounding students' households and schools. This investigation involves collaboration with the Appalachian Division of the National Institutes for Occupational Safety and Health (NIOSH) and the WVU Institute for Environmental and Occupational Health.

Teacher Professional Development

HSTA teachers have the opportunity to enroll each semester in a graduate course (tuition waived to date) that dovetails with their learning experiences and responsibilities as a HSTA teacher-participant. In the Summer semester, the course is "advanced topics" and offered as part of their participation in a two-week HSTA Summer Institute. Throughout the school year (Fall and Spring semesters), the course is "special topics" and related principally to the facilitation of HSTA community-based science clubs. Past course enrollment has ranged from 10 to 13 teachers. Although these are separate courses, the content and assignments are interrelated, and thus should be viewed more as a "package." For example, the "live" contact time with faculty in the advanced topics course that dovetails with the HSTA Summer Institute exceeds what would be expected for a 3-credit graduate course; in the Fall and Spring semester offerings, teacher facilitation of the HSTA clubs constitutes much of the course contact time. Additionally, at the Summer Institutes, teachers gain experience with instructional methods and tools (e.g., "3Ps," concept mapping, graphing calculator) that they apply in the Fall and Spring offerings of the special topics graduate course.

Teachers may elect to count up to 18 credits of this graduate course work towards a 36-credit Master of Arts in Secondary Science Teaching degree program at WVU. Sixty-three (63) percent of the HSTA teachers indicated that the opportunity to earn a Masters degree through HSTA participation was a motivating factor for joining HSTA--currently about one-half (12 individuals) of the HSTA teachers are pursuing this degree. The WVU science education faculty member who is the HSTA community curriculum coordinator also serves as (a) the academic advisor for the cohort of HSTA teachers pursuing this Masters' degree, (b) the instructor of the Fall and Spring semester special topics offerings, and (c) one of several HSTA Summer Institute faculty. Additionally, this faculty member networks with various instructors and special programs in the WVU College of Human Resources and Education to increase the "availability" and utility of other elective and required courses in the HSTA teachers' graduate program. For example, a required course in educational philosophy for the HSTA cohort currently spans the entire school year as opposed to one semester, and is offered on select weekends at a location much closer than the WVU campus for the majority of HSTA teachers. Additionally, several HSTA teachers are fulfilling graduate credit requirements that target trends and methods in secondary science education through WVU graduate courses developed by the West Virginia K-12 RuralNet Project (Wiesenmayer, Meadows, Rubba, Lantz, & Kelly, 1997). This project develops/furthers teachers' INTERNET literacy and ability to utilize the latter as a science education tool, and the course is principally taught "on-line" via e-mail, webboard, listserves, etc.

Students and Research (Cothron, Giese, & Rezba, 1993) and the National Science Education Standards have been principal texts for the special topics courses offered during Fall and

Spring semesters. Course assignments are geared to (a) “make HSTA work” at the community level, (b) facilitate application of what teachers learn and experience in the HSTA Summer Institute to HSTA club programming, and (c) facilitate transfer of what teachers learn in HSTA to their regular science classroom. Additionally, the Spring semester course offering includes an assignment to develop a proposal for a mini-workshop, which teachers conduct at the HSTA Summer Institute to acquaint other HSTA teachers and Summer Institute faculty with science education activities/resources that they have found effective in HSTA club programming. Past mini-workshops have targeted the collection and analysis of data based on the contents of packages of M&Ms™, investigations of the effects of UV radiation on the skin, and the sharing of science project resources from an international conference. A major assignment in the Spring course offering is to facilitate science project data analysis and the preparation and delivery by HSTA students' of science project presentations at the HSTA Annual Science Fair.

Table 2 sets forth an abridged version of the course assignments for the Fall (1996) semester offering. The majority of teachers chose from "additional assignments" the application of the concept map tool--teachers had completed a self-instructional packet (Rye, 1995) and several applied sessions on this tool as preparation for and during the HSTA 1996 Summer Institute. Concept map applications included introducing the idea of "chemistry" and teaching about types of human tissue in high school science courses, teaching about solutions in a middle level science course, and representing and narrowing activities for HSTA club projects. Reflections made by teachers about the utility of the tool were quite positive and indicated an impact on the teachers' regular classroom science instruction--an important goal of HSTA. Excerpts taken from two of the assignments serve as examples of this impact:

> It was the best introduction I've come up with to date. . . .I plan to "reteach" my first day lesson the same way. . .next year and to "revisit" the method as extra credit on the chapter 1 test. It was one of those successful days that makes teaching worthwhile.

> The results were really good. So good, in fact, some of my fellow science teachers are going to try it with some future units and definitely use it next year with this unit. . . .After the mapping activity, I got the response, "oh I see," which made me feel good.

Two to three teachers each chose the graphing calculator application and to write a paper on the National Science Education Standards--assignments which applied other content and tools from the HSTA Summer Institute.

Most of the enrolled teachers have e-mail, which enriches the course and makes more convenient the submission of assignments and communication with the instructor, e.g., the instructor and teachers can exchange URLs and other information found through INTERNET searches as well as listserve e-mail messages that have bearing on HSTA club programming and student projects. HSTA funding has enabled the purchase of notebook computers for use by several of the HSTA teachers/clubs and facilitated connectivity outside of the school setting through INTERNET providers, e.g., Serial Line Internet/Point-to-Point Protocol (SLIP/PPP) connections at West Virginia Network for Educational Telecomputing modem pools located throughout the state. Such also allows teachers to utilize the INTERNET from home, which extends considerably the amount of time they can devote to building INTERNET literacy. HSTA staff plans to expand INTERNET utilization for participating teachers through upgrades to the HSTA Web site (<http://www.hsc.wvu.edu/hsta>), including video conferencing, HSTA club home pages, chat rooms, and more links to "experts" in higher education.

Early in the Fall, 1996, semester, an opportunity arose for teachers to field-test in their HSTA clubs or classrooms nutrition investigations (e.g., laboratory analysis of calcium and iron in foods) that were being developed as a part of an interdisciplinary nutrition high school curriculum by a state department of education. About one-third of all (12) enrolled teachers opted to complete this field test as one of the "assignments designed by you" (Table 2). The topic of human nutrition is well suited to HSTA club programming, because it cuts across many of the health science professions and can be utilized as a vehicle to enhance science and math instruction (Rye, in press). HSTA staff recently received a professional development grant that will enable teachers to learn more about human nutrition and related science and math applications.

Table 2
Condensed Descriptions of Assignments in Fall, 1996, Graduate Course: Curriculum Enrichment Through HSTA Community-Based Science Clubs

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Minimum requirements (i.e., for grade of C)

Attend/complete activities for Fall 1996 HSTA teacher-participant workshop (includes preworkshop readings from the National Science Education Standards)

Conduct (minimum 3 times per month) HSTA science club meetings. Submit monthly report which details content/activities of meetings and your perceptions of understandings, skills, attitudes students developed as a result of each meeting

Facilitate the planning and implementation of student science projects. Submit project proposals (as prepared by HSTA students) for two science projects. Proposals should identify "experts" that will be consulted to insure that the research is feasible, safe, and done accurately.

Submit progress report detailing degree to which you have realized the "things you wanted to do to enhance HSTA club programming" as set forth in writing at the end of the Summer HSTA Institute

If "chat room" and "web board" are established on INTERNET, participate in one "chat room" and post and respond to at least 3 messages on the web board.

Additional requirements for grade of B (complete 1) or A (complete 2)

HSTA parent involvement: Plan and complete session/activity that involves parents in some aspect of HSTA community programming (e.g., inquiry activity at club meeting, students' science project, students conduct session for parents on using INTERNET). Submit outline or description of session, evaluative feedback from parents, and your reflections on the session.

Concept map application: Plan and carry out activity that applies concept map tool in your HSTA club or classroom. Submit purpose/objective(s), description and outline, and "results," including reflections on "how it went" and "what you would do differently next time."

Graphing calculator application: Plan and carry out activity that applies Casio™ graphing calculator in your HSTA club or classroom. Submit same as for concept map application.

National Science Education Standards paper: Submit 3-4 page paper on how HSTA programming is related to one set (e.g., teaching) of Standards. Provide concrete examples of HSTA programming in your paper to support your contentions.

Assignment designed by you: Propose (in writing) what you would like to do related to HSTA programming. Include what will be turned in as evidence of completing assignment and criteria to evaluate assignment. Proposal must be approved by instructor before carrying out.

Evaluation by HSTA Teacher-Participants

HSTA Community Programming

The Office of Health Services Research (OHSR) at WVU carries out the program evaluation of HSTA. After the HSTA 2nd Annual Science Fair in May, 1996, OHSR administered a questionnaire to HSTA teacher-participants ($n = 21$) to obtain their assessment of HSTA community-based programming for the 1995-96 school year. A previous questionnaire, utilized numerous times throughout the 1995-96 school year to solicit HSTA teachers' perceptions of the utility of site visits made by the HSTA curriculum coordinator, aided in the development of this post-science fair questionnaire. The data collected by this questionnaire included responses from HSTA teachers who did not enroll in either the Fall or Spring semester offerings of the special topics (HSTA) graduate courses. It is important to emphasize that HSTA provides a professional development benefit to teachers regardless of their enrollment in these courses. These "other" teachers, some of whom already had a Masters degree, still attended HSTA teacher-participant workshops in the Fall and Spring semesters. Additionally, like all HSTA teachers, they learn from facilitating HSTA science clubs and have the opportunity to "try out" new instructional methodologies and inquiry activities in a "lower risk" environment.

All questions asked teachers to give an open-ended response. Questions that also requested teachers respond on a Likert-type scale (1 = nothing/not effective to 5 = a lot/very effective) elicited their perceptions of (a) how much they learned from their involvement in HSTA club programming, (b) how much they enjoyed their involvement in the HSTA club, (c) how much their HSTA students learned from their HSTA science projects, and (d) the overall effectiveness of HSTA community-based programming. Table 3 provides the mean scale ratings of teachers on these questions, the most common reason (open-ended responses collapsed as possible into logical categories) given to explain their rating, and the frequency of the most common open-ended response.

Table 3
Teacher Evaluation of HSTA Community Programming

Question	Rating	Most Common Explanation for Rating	Percent Giving Explanation
Overall, how much have you learned from your involvement in HSTA Club meetings?[a]	4.2	Learned how to guide student through activities and let students feel ownership in their projects.	24
Overall, how much have you enjoyed your involvement in HSTA Club meetings?[a]	4.3	Enjoyed working with the kids on their investigations.	29
Overall, how much do you feel your students have learned from their HSTA community science project?[a]	4.2	Students learned the value of the research process and experimental design.	29
How would you rate the effectiveness of HSTA community based programs?[b]	4.5	HSTA is good for the students	25

Note: Rating scale for each question was 1 (nothing/not at all) to 5 (a lot/very).
[a]n = 21. [b]n = 20, and excludes one individual who responded "I don't know."

The mean ratings (M = 4.2 to 4.5) provided by teachers, and especially the high rating (M = 4.5) on "effectiveness" of community-based programming, are impressive given that this was the first year of involvement for most teachers and the challenge of engaging students in science and math academic enrichment in an after school setting. Teachers' justifications for their ratings on program effectiveness most often spoke to student benefits, e.g., programming was good for students and students were excited about meeting health professionals and more aware of opportunities. Two teachers responded rather dramatically as to these benefits: "This has been fantastic for my kids. Many would probably be stuck up a hollow with junk around the house the rest of their lives." "HSTA has kept science alive. My HSTA kids are so enjoying the program that I have many kids who want to join."

Teachers' explanations for ratings about their own learning (M = 4.2) and enjoyment (M = 4.3) from involvement in the clubs provided insight into the ways teachers perceived they were developing professionally, and how that compared with professional development outcomes that

HSTA staff hoped teachers were achieving through program participation. Perhaps most important here were that approximately one-fourth of teachers felt they learned how to guide students through HSTA activities and feel ownership in their projects, and that they enjoyed working with the students on these projects. [In response to a different question, the science club activity reported by teachers most frequently (n = 12--more than 50% of teachers) as "liked the best" was the students' community science project and participating in the HSTA science fair that showcased those projects.] Justifications provided by a few of the teachers included "I have learned that my students can learn from their own experiences," "How to phrase questions to help draw students "out"," and that "The kids are terrific. Watching their development as scientific investigators is fun." Another teacher spoke to the difficulty of changing his or her instructional paradigm: "I've learned to give the students more freedom in their learning, but it is still hard to give up old habits." Other reasons provided by teachers to justify their ratings about how much they learned from HSTA spoke to additional benefits HSTA staff hoped to provide the teachers, and included that they learned "how to be more confident in teaching experimental design," "many techniques and teaching strategies and have been able to incorporate them into my classroom," and "more about my community and know there are many untapped resources."

Teachers rating of how much students learned (M = 4.2) from their science project was most commonly justified by stating that students learned the value of the research process and experimental design. Almost one-fourth of the teachers also explained their rating by stating that students learned basic knowledge about the subject that they were researching. One teacher's response was rather blunt, yet spoke directly to the "opportunity" provided through academic enrichment programs such as HSTA: "I feel that they learned a lot of information that they would never have learned elsewhere."

The group of HSTA students attending the HSTA 2nd Annual Science Fair also were surveyed to determine their perceptions of what they had learned from their HSTA science project. One hundred and fourteen students responded, and the mean rating (1-5 Likert-type scale) was 3.8 (excludes two students who responded "no opinion"). Most frequently (18% of students),

students reported learning "a lot" with no specific details given. The most frequent content area cited was water quality. Two students' explanations are of particular interest, as they spoke to critical characteristics desired in the learning atmosphere of HSTA clubs and corroborated teachers' explanations: "I learned a lot of stuff about water that I never really new before and I was really interested" and "You learn a lot by doing and going over the other projects with friends."

Students also were queried as to how much they felt their HSTA teachers encouraged them to "explore their ideas." This question is critical to HSTA programming, because student interest is paramount to HSTA club attendance. The mean response was 4.3. Almost one-half of the students' justifications could be collapsed into this reason: The teachers encouraged and supported them through giving guidance and assistance with the decision making process in the exploration of their ideas. Such speaks to the paradigm shift explicit in science education reform, which HSTA attempts to realize: from teacher directed to student centered learning.

Special Topics Graduate Course

To date, evaluation data are available only for the Spring, 1996, graduate course offerings that dovetail with HSTA teachers' responsibilities as facilitators of HSTA community programming. Ten teachers finished the course, and seven of them completed and returned by mail to OHSR a course evaluation questionnaire that was adapted from the standard university (WVU) course evaluation tool. Four of the teachers rated the course "excellent" and three rated the course "good" (other choices were satisfactory, fair, and poor). An important addition to this tool was the question: To what extent did the course contribute to your professional development? Given the choices "not at all," "somewhat," "moderate extent," and "great extent," all 7 teachers chose the latter. Five teachers provided reasons to support their rating, and each reason spoke to qualities and outcomes desired by HSTA staff. One reason was quite comprehensive: "I learned a great deal from participating in HSTA, both about the health science fields and about our specific health-related project. I have met a lot of new people and gained a lot of resource materials and personnel."

Other teachers stated that the course "went along with what we were actually doing with students" or was an "incentive to keep trying when we have one of those periodic HSTA meetings that makes you wonder if you are having an effect on the students." One just put it like this: "I feel that I as well as my kids in HSTA have changed from a "frog" to a "prince"."

When asked to provide other comments, including those pertaining to course improvement, only one individual cited an improvement: More workshops. Other questions solicited directly the teachers' satisfaction with the instructor's written communication, teaching, and knowledge, and are not dealt with in this paper.

Conclusions

HSTA provides a special opportunity for teachers to "make a difference" in the future lives of underrepresented students, and gain extensive professional development in doing so. Through facilitating extracurricular science clubs, these teachers make possible science and math enrichment for students as well as the opportunity to learn more about and experience through shadowing careers in the health sciences.

Broadly, HSTA makes important contributions to the National Education Goals (America 2000, 1991)--to be first in the world in math and science and to provide professional development for educators. More specifically, HSTA facilitates the realization of the National Science Education Standards as they pertain to teaching, professional development, content, program and system. Examples of related HSTA thrusts include a primary emphasis on learning science through inquiry, access to community and university resources (including "the medical establishment") that extend the school science program beyond the "walls" of the school, extended investigations that nurture a community of learners, increased emphasis on the teacher as a member of a professional collegial community and as a source and facilitator of change, and equity of science education opportunities for underrepresented youth.

The provision of science and math enrichment to underrepresented youth (many from rural areas) through "after school" programming represents a major challenge, and teachers are the most important learning resource in this endeavor. Therefore, it is significant that teachers evaluate highly community-based HSTA programming to date and find personal meaning and benefit in their involvement, and that the latter includes the application of knowledge and skills gained from HSTA to their regular science classroom. Anticipated applications of communication technology (e.g., video conferencing and HSTA club home pages) should contribute further to collaboration amongst HSTA teachers, students, and faculty in higher education.

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MATHEMATICS AND SCIENCE TEACHING PROJECT BASED UPON INFUSION OF NATIVE AMERICAN CULTURE

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Introduction

Imagine a television news broadcast interrupted with a bulletin announcing that a vehicle from outer space has landed in a remote area in Yellowstone Park. Individuals with skin color and facial features not familiar to us have stepped out and, through a sophisticated language conversion device, have been able to communicate with people in the surrounding area.

The foreign individuals appear friendly and seem genuinely interested in our people, customs and way of life. They have demonstrated superior weapons and various other forms of technology which have our military very worried.

Soon the visitors have made it known that they would like to live here. A small group of senators travel from Washington, D. C. to confer with them. Almost immediately the senators are psychologically overwhelmed by the visitors' advanced technology and the superiority of their weapons. In a ceremony in which an intoxicating milky liquid is served, the senators sign over 100 square miles of Yellowstone National Park for the visitors to colonize. Numerous baubles of sophisticated software and hardware are bestowed upon the senators. All of the "gifts" are highly sophisticated by our standards, but are really considered outdated junk by the visitors.

Almost immediately the colonization begins. Permanent structures become part of the landscape. A group of United States tourists wander into the visitors housing area and are destroyed by their security systems. The local national guard is called out and is immediately annihilated. Negotiations end with the ceding of the entire state of Wyoming, with the local residents being relocated into the Nevada desert. More visitors arrive from outer space and more territory is ceded. Soon, it is obvious, the entire country belongs to the visitors. It becomes futile to resist. Occupants of the relocation centers lapse into a sense of hopelessness. Becoming inebriated with the white liquid becomes more and more a way of life for many.

The preceding scenario is a very dismal situation from our perspective. We were living in peace and harmony, and in a relatively short time, our lives were changed to an almost impossible situation. We were quickly subdued by superior numbers and an advanced technology.

A parallel situation existed for Native Americans on the North American continent with the advent of the Europeans. These people were forced into reservations in geographic areas where it was impossible to sustain life. Clothing, food, and shelter were promised through treaty by our Federal Government, but delivery was often tentative and sporadic. People had no gainful employment and lost dignity and developed low self-concepts. The hopelessness of reservation life has led to many problems for Native American people.

Project

Purpose

An Eisenhower supported project was implemented to improve the grades K-12, teaching of science and mathematics in the Tiospa Zina Tribal School (TZTS), Agency Village, South Dakota. The project activities were based on the infusion of the Native American culture, the utilization of hands-on science and mathematics techniques, the integration of science, mathematics, technology, and cooperative learning through:

1. A one-week summer inservice training workshop in the TZTS
2. Eight inservice follow-up sessions during the 1994-95 academic year, and
3. Mail loan of science/mathematics materials from the USD Northern Plains Science/Mathematics Education Resource Center during 1994-95 academic year.

Focus

The summer institute and the follow-up inservice concentrated on faculty enhancement in Native American cultural background, faculty infusion of Native American culture into the teaching of science and mathematics, and enablement of indigenous students to make connections with their cultural roots and the learning of science and mathematics.

Teachers designed and implemented activities in science and mathematics to facilitate the student outcomes previously adopted by the TZTS:

1. Effective Communicators who demonstrate the ability to express themselves clearly in all aspects of life.
2. Enlightened Representatives who incorporate principles of Dakota culture, modern and traditional values, and tribal affairs into their daily lives.
3. Self Directed Achievers who formulate goals and priorities, and continuously evaluate their progress.
4. Balanced individuals exhibiting sensitivity, self confidence, and respect, who model holistic lifestyles and are able to live in harmony with self, others, and Mother Earth.
5. Creative thinkers who use a variety of techniques and resources to resolve challenges facing them.
6. Global citizens who demonstrate respect for and acceptance of cultural diversity.

Twenty science and mathematics and elementary teachers were involved in the Project. The teachers suggested the dates and meeting times for a one-week workshop in the TZTS during May 30 - June 4, 1994, as well as eight inservice academic year meetings.

Rationale

Students view teachers as the single most important influence on their science attitudes (Westerback, 1982). Numerous professional organizations have set the direction for the teaching of mathematics and science.

The National Council of Teachers of Mathematics advocates mathematics teaching which is student-centered, activity centered using technology and manipulatives, and is designed to promote higher level thinking and exploration. Mathematics students should be empowered to "analyze, reason, and comprehend."

Both the American Association for the Advancement of Science (AAAS, 1989) and the National Science Teachers Association (NSTA, 1992), advocated hands-on, inquiry-based teaching with students doing science. The National Science Foundation Statewide Systemic Initiative (NSF-SSI) project placed emphasis on the teaching of science and mathematics using manipulatives, problem-solving-inquiry processes, infusing technology, integrating science, mathematics, language arts and social studies and the community.

Evidence over the past three decades consistently verifies the efficacy of the activity/inquiry approach to teaching science. Meta-analyses of hundreds of experimental studies involving thousands of students indicate the hands-on inquiry curricula as superior to traditional curricula in achievement, reading readiness and skills of analysis, math, social studies, communication, and positive science attitude development. (Bredderman, 1983; Shymansky, et.al., 1983).

The Tiospa Zina Tribal School (TZTS) consists primarily of Native American students. Present-day Native American students tend to either buy into the cultural values of the indigenous culture, buy into the values of the dominant society, function in both the indigenous culture and the dominant culture, or buy into neither.

It appears that increasing numbers during the past decade buy into neither culture. Having little, if any, cultural roots from which to realize stability, these young people exist in flux, have a high probability of not realizing their potential, or at worst have a high potential of dropping out of society. If young Native Americans are not taught the values of the indigenous culture, there are serious implications that they lack knowledge and lack understanding and feel out of touch with reality, feel adrift and perhaps even ashamed to be "Indian."

A Native American Adolescent Health Survey, administered during the spring of 1993, indicated that 53% of the TZTS Grades 6-12 students are emotionally insecure or unsure of self, find daily life uninteresting, and 61% feel their family cares little about feelings.

It seems reasonable to educate Native American students in their basic cultural heritage for maximum utilization to fit into the dominant society. Both Jewish and Asian cultures successfully maintain their strong cultural heritages while successfully integrating into the dominant society.

The TZTS had previously derived a very pivotal Mission Statement which was quite complementary to the purpose of the project. As a broad vision statement, it encompassed all of the project ingredients throught the statement on the following page.

To provide students of the Tiospa Zina Tribal School with educational opportunities which will prepare them to function in a multi-cultural and increasingly technological society while retaining their unique cultural heritage and identity.

The proposed project focused on the indigenous stories from the past, which could be gleaned from the local community as well as sources of Native American writers, and used them as the basis for studying mathematics and science. Examples of excellent sources of Native American stories, and associated teaching suggestions are Native American Stories (Caduto & Bruchac, 1991), Keepers of the Animals (Caduto & Bruchac, 1991), Keepers of the Earth (Caduto & Bruchac, 1989), and Earth's Caretakers, Native American Lessons (lessons patterned after the Robert Karplus Learning Cycle), (Nyberg, 1993).

Careful analysis of the traditional stories indicates a correspondence between them and the current theories of science and mathematics. Ecologists routinely warn us that our future health depends of the interrelationship between ourselves, our planet, and the plants and animals in our environment. The indigenous peoples viewed the natural world in balance with all things, including themselves, as part of a great circle. Humans were not more important than the rocks, the plants or the animals. In fact, it is not uncommon for them to be described as "ancestors" and for stories to include people becoming animals and animals becoming people. Therefore what was done to nature was done to a brother or sister. They emphasized a harmony with nature rather than control of nature. The people believed they were living with rather than on the place they called turtle island. If people became sick, it was viewed as an imbalance which must be restored. The Creator was ubiquitous requiring ceremonies and prayers which involved the sick person's entire community. "The old Lakota was wise. He knew that man's heart away from nature becomes hard. He knew that lack of respect for growing living things soon led to lack of respect for humans too." Chief Standing Bear, Oglala Sioux (Nyberg, 1993).

The view of the "old Ones" is as apropos today as it was for centuries in the past. Michael J. Caduto emphasized this perspective: "We are in relationship with the Earth and other people. Doing good supports this relationship. Love and moral goodness are inseparable, they are the elemental components of a life ethic." (Caduto, 1985).

N. Scott Momaday stressed the importance of stories in the indigenous culture: "In his traditional world the Native American lives in the presence of stories. The storyteller is one whose spirit is indispensable to the people. --- his object is most often the establishment of meaning. --- stories tend to support and confirm our perceptions of the world and of the creatures within it. ---The stories in the present collection center upon one of the most important of all considerations in human experience: the relationship between man and nature. In the Native American world this relationship is so crucial as to be definitive of the way in which man formulates his own best idea of himself. In the presence of these stories we have an affirmation of the human spirit.It is a just and wondrous celebration." (Selected parts of the Foreword by Momaday in Caduto & Bruchac, 1989, p. xvii)

The intent of the project was not to teach Native American cultural values, but to instruct the teachers in utilizing Native American Cultural background and values in teaching mathematics and science. Much of Native American culture, such as the circle, the drum, the sweat lodge, etc., enter into the spiritual realm. Participants involved in the project activities were encouraged to exercise sensitivity in all lesson planning.

Activities

Twenty K-12 teachers from the Tiospa Zina Tribal school attended a May 30 - June 4, 1994 summer institute in the Tiospa Zina school. Participants elected 3-semester hours of graduate credit in the course Developing Hands-on/Inquiry-Based Mathematics Science Teaching Strategies, at no tuition cost

Activities were conducted by the PI, professor of science education, an associate professor of Native American Studies (a Lakota speaker), and an assistant professor of Mathematics Education. Concentration was on problem solving thinking skills, cooperative learning, the use of manipulatives, and the integration of science/mathematics based upon stories and background of the Dakota culture.

The Native American studies professor developed background in Native American cultures which gave a theoretical perspective to the participants. He tied in specific generic teaching procedures for enhancing the learning of Native American students.

The mathematics education professor worked with the mathematics teachers in developing the use of manipulatives in the teaching of mathematics. Tenets of the NCTM Standards were incorporated.

Science education activities were the responsibility of the PI. He also was responsible for planning of the activities and gave special effort to coordinate Native American cultural infusion and the integration of science, mathematics, and technology. In response to a teacher bringing in several milk cases of Native American resources available from the school and the personal libraries of the faculty, the PI urged the high school principal to have the titles, authors, and location of the materials entered into a computer data base for easy sorting and access. The information was entered into a spreadsheet which at least makes them easily accessible, but does not have the sorting capabilities offered in a data base.

The summer institute activities were based on the Jean Piaget cognitive developmental theories through the Learning Cycle developed by the late Robert Karplus. Experimental evidence has demonstrated the efficacy of the Learning Cycle which is endorsed by the Council for Elementary Science International (CESi). The Learning Cycle consists of three sequential steps; Exploration, Concept Introduction, & Concept Application. Each participant planned a Learning Cycle lesson incorporated with a Native American component, and in turn, taught the lesson to the group, followed by a group critique.

Project Learning Tree and Project Wild were introduced to the group with personal copies provided each participant. Each of these environmental educational sources contains lessons incorporating Native American culture with the study of science and environmental issues. The participants were also involved in activities from Project AIMS (Activities for Integrating Mathematics & Science).

During the 1994-95 academic year, eight, four-hour, inservice sessions were conducted in the TZTS on a Monday afternoon. Classes were dismissed in the school for staff development activities for the project as well as outside the project. New materials and activities were introduced, and the participants shared lessons they had taught and classroom experiences as well as problems and successes they encountered. Participants were asked to design at least two Learning Cycle lessons each month and teach them to their classes. The lessons were demonstrated during the sessions and critiques were given as to the efficacy of their lessons with their students. Questions were fielded from the other participants.

Evaluation: An Overview

Analysis of both the summer institute survey of participants' perceptions as well as that done on the survey of the academic year activities reflected high participant satisfaction. The predominance of participants viewed the experiences as being quite valuable.

Sixteen of the 20 participants completed the University credit requirements. Four of the individuals fell behind in their assignments and received incompletes at the end of project activities. One individual had been involved in a Master of Arts program and was able to complete the degree requirements during the project year. This individual asked the PI to serve as her major advisor.

As a result of the program, the TZTS became interested in functioning as a Professional Development Center (PDC). During the spring of 1995 a contractual agreement was reached between the TZTS and the University of South Dakota. Two TZTS teachers were released from classroom duties to serve as mentors for two PDC teachers. Both the mentors and the PDC teachers were enrolled in graduate programs. Graduate courses were offered in the PDC with non-PDC teachers as well as PDC personnel enrolled in the graduate courses and graduate programs. One mentor teacher, the same person who completed her Master of Arts program as an advisee of the PI, is completing a doctoral program. Mentors were also involved in inservice work and curricular and program improvement in their school as well as being involved in mentoring the PDC teachers.

The superintendent of the TZTS is keenly interested in curricular development as well as staff development. He has been instrumental in the development of a curriculum guide, based on Outcome Based Education, which had been designed with considerable emphasis on educating the whole student in becoming a well adjusted, productive citizen, able to function in modern society while maintaining cultural roots. It is his desire to have all of the teachers in the system to earn masters degrees or above. It appears that the project described in this article has been of benefit to a number of teachers in this school system who are postured to utilize their experiences for the benefit of their students. A number have completed advanced degrees. The project has also been a mechanism to stimulate the faculty and administration toward further staff enhancement.

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POLICY ISSUES IN FLORIDA TEACHER EDUCATION - ROLE AND IMPACT OF THE HIGHER EDUCATION CONSORTIUM FOR MATHEMATICS AND SCIENCE

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The Florida Higher Education Consortium for Mathematics and Science

If systemic reforms of science and mathematics teaching and learning are to occur, leaders at all educational levels and community leaders must develop new structures to guide and support the change efforts (AAHE, 1994; Haycock, 1994). College faculty must accept and personalize constructive change in inquiry-based communities (Halpern, 1994; Project Kaleidoscope, 1991; Tobias, 1992).

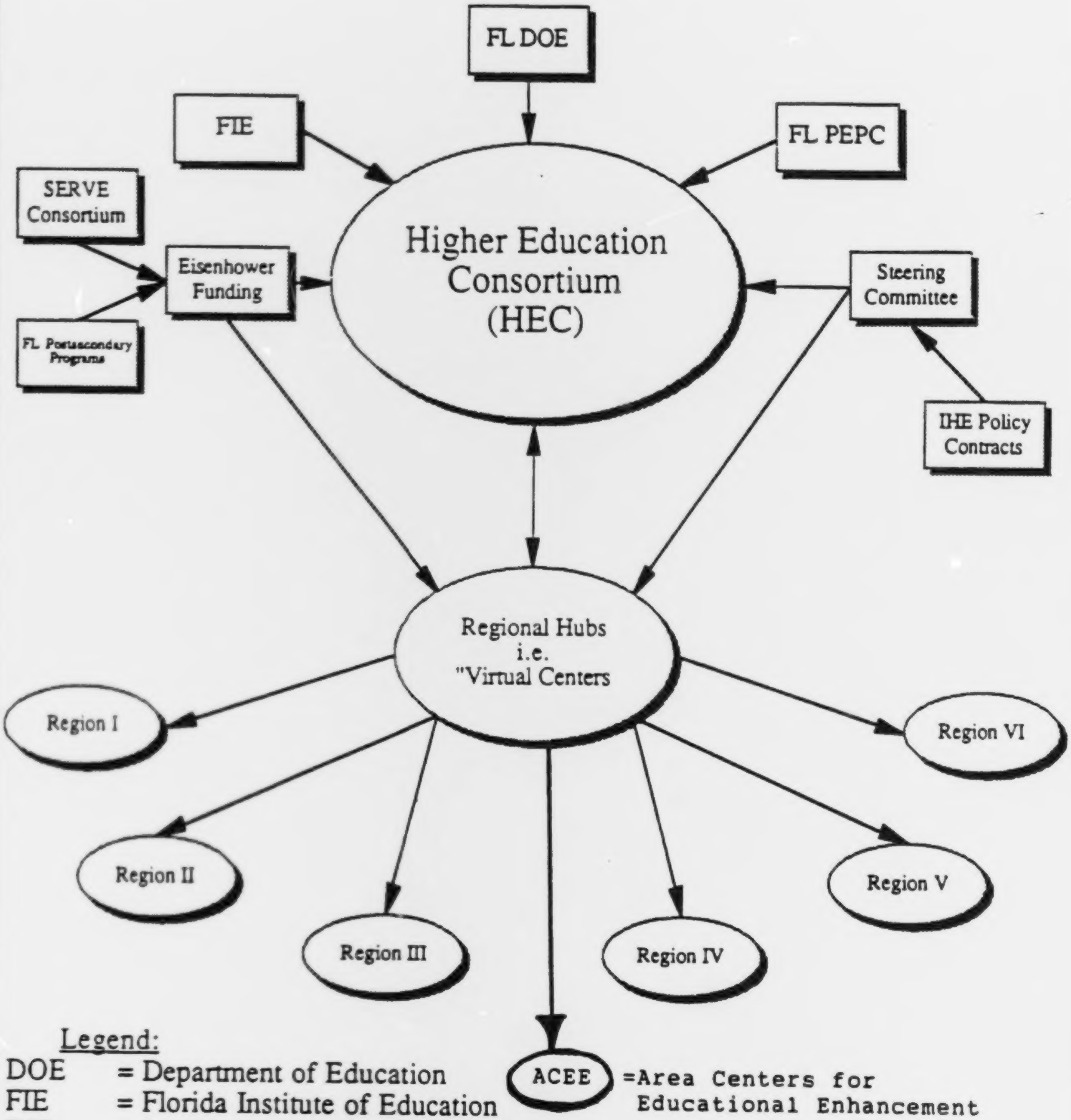
In Florida new organizational structures have been created to involve higher education faculty in working with one another and with their preK-12 colleagues. The Florida Higher Education Consortium for Mathematics and Science (HEC) is a virtual center composed of state universities, community colleges, private colleges and universities and other entities in six geographical regions corresponding to the Florida Department of Education organizational structure.

Since Fall 1993, the HEC has received funds from the Florida NSF/State Systemic Initiative and the Postsecondary Eisenhower program (federal flow through dollars). In addition, the HEC has aligned its efforts with the Southeast Regional Eisenhower Laboratory (SERVE), the Florida Postsecondary Education Planning Commission (PEPC), and the Florida Institute of Education (FIE). A steering committee consisting of a chair, six regional representatives, and other agency representatives has served as the policy board for the HEC. Figure 1 elucidates the HEC organizational structure.

HEC activities occur regionally and statewide, with the past statewide meeting and the projected 1997 meeting occurring in conjunction with the Conference on College Teaching and Learning, an international meeting hosted by Florida Community College at Jacksonville. The HEC continues to evolve and expand into an entity which encourages communication, strategic planning, research and evaluation. While new community college, college, and university members are actively recruited, the HEC facilitates meetings between higher education and elementary/secondary teachers and administrators at both the regional and statewide levels. HEC

Figure 1

FLORIDA
HIGHER EDUCATION CONSORTIUM for MATHEMATICS and SCIENCE
ORGANIZATIONAL STRUCTURE


FL DOE
FIE
FL PEPC
SERVE Consortium
Eisenhower Funding
FL Postsecondary Programs
Higher Education Consortium (HEC)
Steering Committee
IHE Policy Contracts
Regional Hubs i.e. "Virtual Centers
Region I
Region VI
Region II
Region V
Region III
Region IV
ACEE

Legend:

DOE = Department of Education

FIE = Florida Institute of Education

IHE = Institution of Higher Education

PEPC = Postsecondary Educational Planning Commission

SERVE = South Eastern Regional Vision for Education (Regional Eisenhower Consortium)

ACEE =Area Centers for Educational Enhancement sessions have been presented at the statewide science and mathematics teachers' meetings.

Goals of the HEC

Four goals and a mission statement were established at the December 1993 HEC meeting at University of Central Florida in Orlando. These have been refined and expanded, with corresponding activities and expected outcomes. The stated mission of the HEC is to serve to facilitate communication among higher education institutions as a basis for enhancing mathematics and science teaching and learning. Goals and sample activities are as follows:

Goal 1: Continue to establish HEC as a viable, virtual center that works to enhance mathematics and science education.

A representative steering committee has operated since Fall 1993 to guide HEC activities. The composition reflects mathematics and science at university, college, and community college levels.

Goal 1 Sample Activities

1. Refine communications among institutions and between HEC and local, state, and national policy makers; explore ways to strengthen collaborative relationships which support the comprehensive goals of systemic reform.
2. Facilitate professional development opportunities for HEC members, especially those which focus on reconceptualizing teaching and learning science and mathematics at the post-secondary level; include distance technologies.

Goal 2: Enhance the utilization of educational programs and resources.

The HEC is dedicated to enhancing the quality and cost-effectiveness of relevant programs by sharing resources and ideas.

Goal 2 Sample Activities

1. Identify programs and models that reflect HEC goals. Develop a clearinghouse and database of relevant information/expertise.
2. Work with other HEC members, school districts, and informal learning centers to share, resources and educational programs of merit.

Goal 3: Reconceptualize and restructure teacher education by developing models that meet the unique needs of educational communities.

The HEC is working with the Florida Department of Education and the Florida Education

Standards Commission to conceptualize and implement effective approaches to teacher development.

Goal 3 Sample Activities

1. Study and discuss the Mathematics and Science preK-12 Curriculum Frameworks and Sunshine State Standards, the Science Teacher Development Framework, the Educational Standards Commission Educator Accomplished Practices, national-level science and mathematics standards documents, and other relevant reform documents, including innovative teacher preparation and enhancement models; focus on deep analysis of pedagogical and content issues, including science and mathematics courses/experiences and field experiences.
2. Sensitize the higher education community to the critical need to address diversity and equity in teacher education models, including recruitment and retention issues.
3. Take an active role in the establishment of teacher education policy, i.e. certification, FTE requirements, accreditation, etc.

Goal 4: Evaluate the systemic impact of HEC on the enhancement of mathematics and science teaching and learning at state, regional, and local levels.

The Research and Evaluation Task Force of the HEC is constructing a model for evaluating systemic change based on systems theory.

Goal 4 Sample Activities

1. Develop and implement an ongoing mechanism to evaluate the activities of HEC.
2. Provide interactive forums to discuss HEC research and evaluation plans and results and to partner in the development of a statewide research agenda.

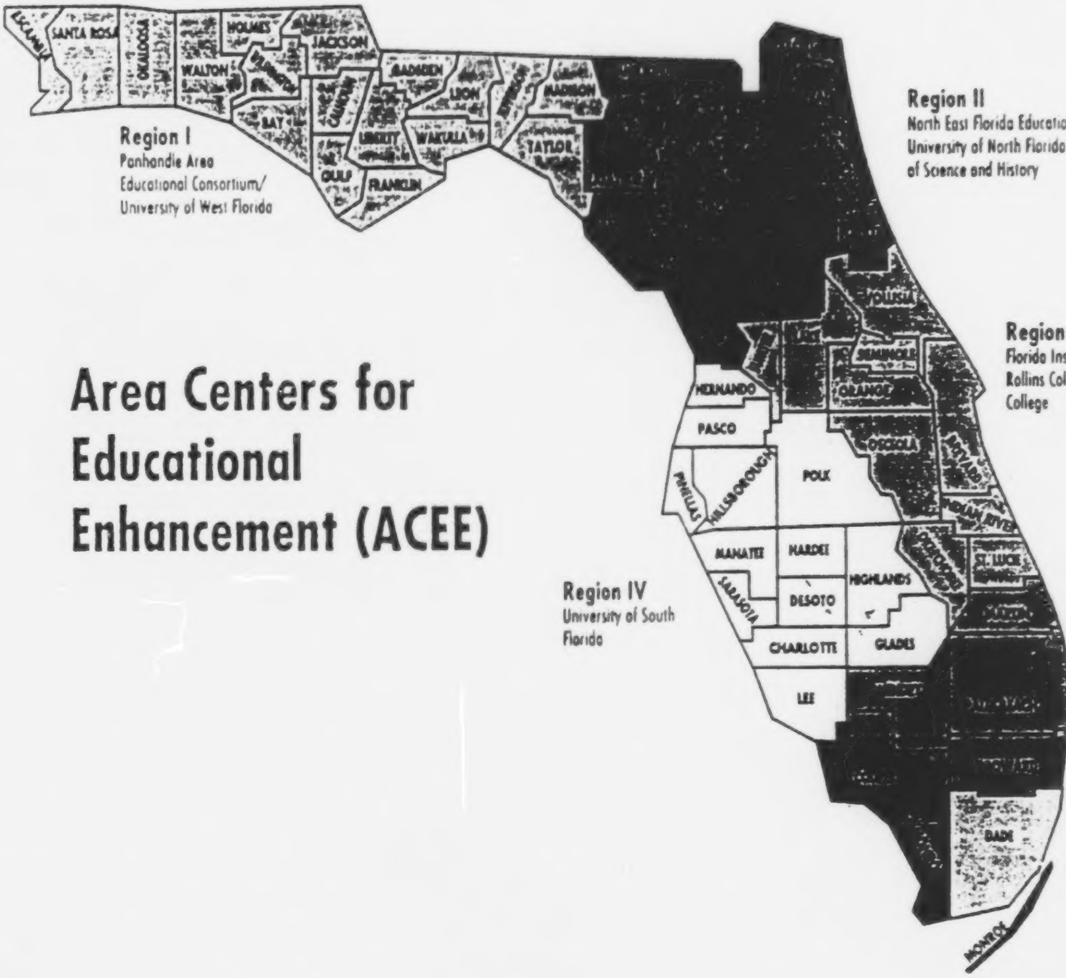
Area Centers for Educational Enhancement

In summer 1996, all HEC Eisenhower funding was included under the umbrella of a new Florida DOE initiative, the Area Centers for Educational Enhancement (ACEE), funded at a maximum of $600,000 per center including approximately $260,000 which must be administered by a higher education institution. These centers serve all school districts in their respective regions and model a k-16 educational continuum. Figure 2 depicts the geography and lead institutions of the six Florida Area Centers for Educational Enhancement.

A Regional Example

An example is the following. Twenty school districts are in the northeast Florida "Crown"

Figure 2


ESCAMBIA
SANTA ROSA
OKALOOSA
WALTON
HOLMES
JACKSON
WASHINGTON
BAY
CALHOUN
GADSDEN
LEON
JEFFERSON
MADISON
LIBERTY
WAKULLA
TAYLOR
GULF
FRANKLIN
VOLUSIA
SEMINOLE
ORANGE
OSCEOLA
BREVARD
INDIAN RIVER
OKEECHOBEE
ST. LUCIE
HERNANDO
PASCO
PINELLAS
HILLSBOROUGH
POLK
MANATEE
HARDEE
SARASOTA
DESOTO
HIGHLANDS
CHARLOTTE
GLADES
LEE
DADE
MONROE

Region I
Panhandle Area
Educational Consortium/
University of West Florida

Region II
North East Florida Educational Consortium/
University of North Florida and Museum
of Science and History

Region III
Florida Institute of Technology/
Rollins College/Bethune-Cookman
College

Area Centers for Educational Enhancement (ACEE)

Region IV
University of South
Florida

Region V
Broward Community
College/Florida
Atlantic University

Region VI
Dade County Public
Schools/Florida
International University

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region (Region II) and are represented by the the Northeast Florida Educational Consortium, which serves as the preK-12 fiscal agent for the ACEE. The higher education institution serving as the regional coordinating HEC Center (University of North Florida) has committed to continuing HEC activities by working closely with the Crown Region ACEE and all ten colleges, universities and community colleges in the region. It functions as an interdisciplinary center which links faculty efforts in the College of Arts and Sciences and the College of Education.

Regional Steering Committee

A steering committee consisting of the Deans of the two colleges and representatives of relevant departments and a core group of Region II HEC members guide intra and inter institutional collaboration. Faculty are supported for their efforts which include reforms in science and mathematics and science and mathematics education courses and programs. Since these reforms are major goals of HEC, this center serves as a model for other higher education institutions in the Crown Region. The presence of the HEC center and its relationships to other institutions of higher education and school districts in the region catalyze efforts to secure other federal, state and private sector funding.

Regional Teacher Enhancement Model

NEFEC and the Region II HEC have developed a Teacher Enhancement Model which aligns school district resources and involves both district personnel and college faculty in district training teams and preservice teacher education program development (See Figure 3).

HEC Policy Issues

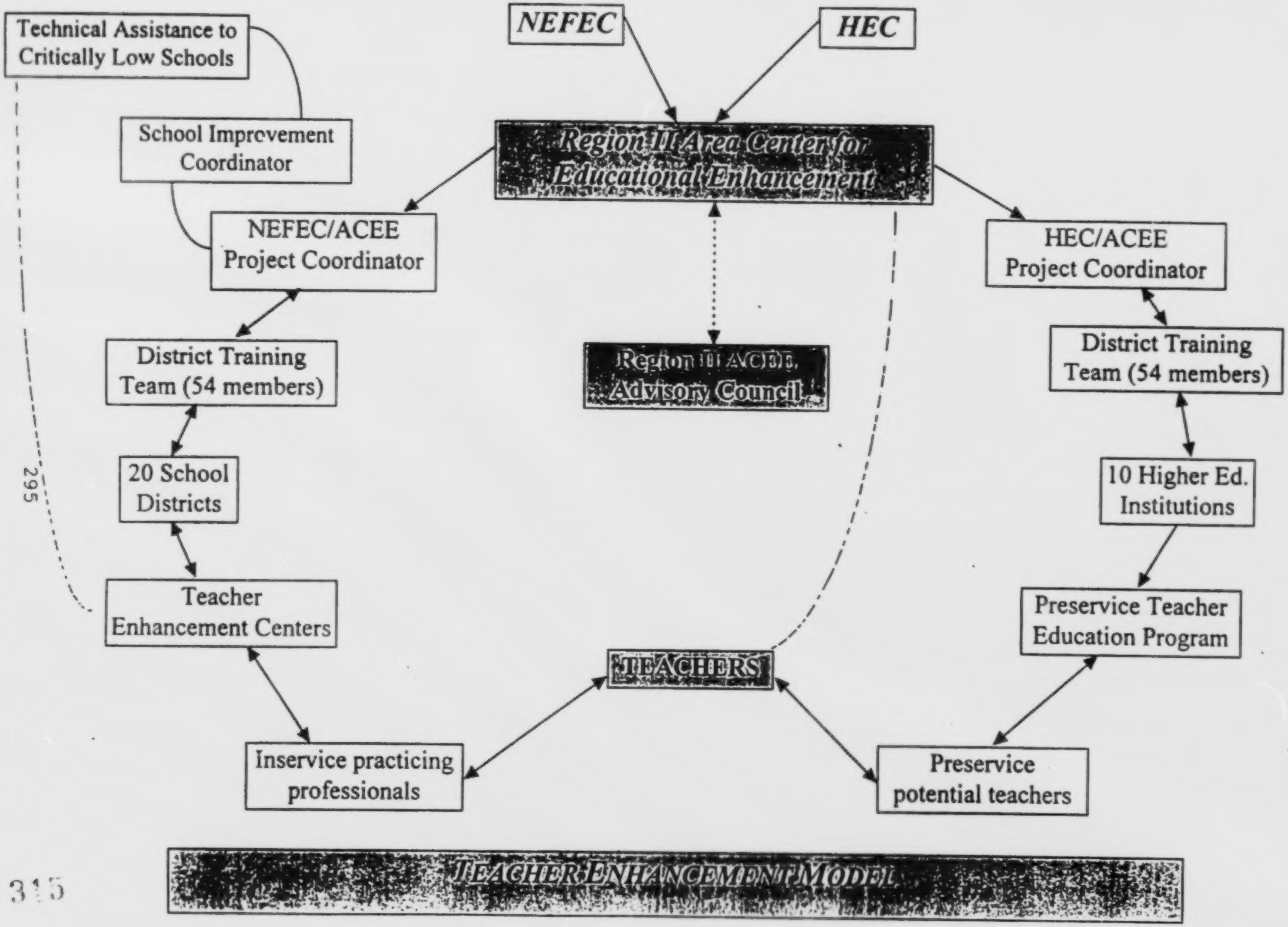
While HEC has been instrumental in planning and participating in science and mathematics teacher education reforms, a number of questions must be addressed if policy changes are to occur and endure over time. These questions will inform the proposed research and evaluation activities of the Florida HEC.

Challenging Questions

The questions are as follows:

- Who are the members of HEC and how representative is it of the various entities which need to be involved in effective teacher education reform? What incentives keep HEC members actively involved in regional and state level activities?
- Who are HEC's major partners and how have relationships progressed?

Figure 3


NEFEC
HEC
Technical Assistance to Critically Low Schools
School Improvement Coordinator
Region II Area Center for Educational Enhancement
NEFEC/ACEE Project Coordinator
HEC/ACEE Project Coordinator
Region II ACEE Advisory Council
District Training Team (54 members)
District Training Team (54 members)
20 School Districts
10 Higher Ed. Institutions
Teacher Enhancement Centers
Preservice Teacher Education Program
TEACHERS
Inservice practicing professionals
Preservice potential teachers
TEACHER ENHANCEMENT MODEL

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- How have HEC members become partners in preparing teachers and determining national and state standards-based criteria for program design and accreditation?
- How is HEC addressing the need to include more under represented groups in science and mathematics education?
- How have HEC members provided support for the articulation between K-12 education and higher education?
- How is the HEC planning and implementing research and evaluation plans? For example: How is the ACEE/HEC model functioning? What are the indicators used to judge its effectiveness? How much variation occurs in ACEE/HEC models among regions? How are diversity in design and commonality in purpose sustained?
- How has HEC become involved in inter institutional distance learning?

HEC as Case Study

The HEC has adopted the mission to facilitate communication and improve teaching and learning in Florida by focusing on inter institutional collaboration. It engages in alignment, analysis, and action. With a statewide database of more than 500 members and even more members active at the regional levels, HEC has focused the energies of Florida faculty on areas of common interest, both institutionally and personally. Through shifts in policy and funding at the state level, HEC continues to endure and grow. Lessons learned continue to provide engaging challenges for Florida educators. The Florida story is a case study of potential use to other states engaged in the meaningful reform of science and mathematics education.

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COMPARING TEACHING PRACTICE WITH STUDENT OUTCOME KNOWLEDGE: AN ASSESSMENT OF MID-LEVEL CONSTRUCTIVIST LEARNING ENVIRONMENTS

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Problem

Inquiry-oriented instruction is complex requiring teacher expertise, appropriate materials, and cooperation of students. Research on inquiry-oriented instruction has focused more on student behaviors and their connection to a variety of learning outcomes than it has on the behavior of teachers and how they establish and maintain inquiry-oriented instruction (Romberg & Carpenter, 1986; Reid & Hodson, 1987). Empirical studies of student learning in inquiry contexts often highlight positive exemplars that show the possibilities of inquiry as an instructional model (Roth & Roychoudhury, 1993). These examples have been tantalizing and inspiring but leaves us wondering what the teacher is doing (Hofstein & Lunetta, 1982). This knowledge raises the question of how teachers operating in typical classrooms generate inquiry-oriented learning environments? Equally important is how do all of the students in a classroom, no just interesting exemplars, interpret and react to this type of instruction?

Given the constructivist-based, inquiry-oriented instruction promoted by the National Science Education Standards (NRC, 1996), a major challenge in science education is to develop comprehensive theory about the behavior of teachers and students in classrooms that implement recommended practice. The popular view of successful teaching envisions well-planned, smoothly-executed lessons that culminate in anticipated student behaviors that meet pre-planned objectives. However, expertise in teaching is perhaps more appropriately characterized by how the teacher manages divergence and impediments to planned instruction (Sternberg & Horvath, 1995; Hammer, 1997). Teaching is an ongoing intellectual challenge requiring teachers to reflect on content, adjust pace, probe individual students, and even change instructional objectives while they are teaching a lesson (Tobin & Fraser, 1990; Tobin, Kahle, & Fraser, 1990).

A more fluid, realistic, real-time view of instruction is more difficult to track and to document. Understanding the dynamics of the everyday classroom under the influence of a complex form of instruction requires studying the relationship of many people, their knowledge, beliefs, and intentions. Investigating deep questions about classroom contexts usually suggests broad based, qualitative research techniques. This study used the context of a broad based intervention in elementary and middle level science teaching to document several aspects of instruction from a documentation of teaching practice to students outcomes.

Purpose

This is study is derived from the evaluation component of an NSF-funded project entitled: Integrated Science Concepts (ISC). The purpose of the study was to assess student knowledge that resulted from differential implementation of constructivist-based, inquiry-oriented teaching practices demonstrated during ISC workshops. Because the specific nature of instructional practice was left to the discretion of each teacher, data were also collected concerning individual teacher beliefs and teaching practices with respect to constructivist teaching.

Subjects

Three middle level teachers and one 5th grade teacher were selected from those participating in ISC. Teacher selection was based on criteria derived from observations during ISC workshops, from lesson plans and journals required by the project, and from video tapes of classroom teaching taken after the summer workshops. These data were used to select teachers who represented a range of teaching skills with respect to the constructivist objectives of ISC (see Table 1). Observations of teaching and assessment of workshop participation involved high inference techniques. Specific teaching practices were not the focus of workshops nor was constructivist teaching operationalized by ISC in such a way that specific observation criteria could be applied in classrooms. Consequently, judgments made in selecting teachers were based on subjective criteria derived from familiarity with the research literature on constructivist teaching, workshop content, and the teachers themselves. Ranking by observation criteria is reported because it reveals a interesting disparity with the ranking by Constructivist Learning Environment Survey (CLES) (Enochs & Riggs, 1990) scores collected in July.

Each teacher used their own judgment to select approximately six students for interviewing. Selection criteria was that the student sample provide a cross section of conceptual understanding of the science subject matter and an even distribution between males and females. Teachers also estimated which students would be most willing to voluntarily participate in these interviews and therefore provide the maximum amount of information (see Table 2).

Insert Table 1 about here

Insert Table 2 about here

Methods

Teachers participated in two, 45-minute interviews conducted by different external evaluators. Both were conducted at the end of the year after incorporating recommended practices. Both interviews elicited discussion of beliefs about teaching related to constructivist practice. The first interview focused on teacher understanding of specific science knowledge presented as a part of the summer workshops conducted nine months earlier and a general assessment of what students learned as a result of teaching a portion of that content. The second interview focused on a validation of their responses to the CLES and a discussion of specific teaching practices.

The six teachers collaborated with the two evaluators in the design of interview protocols used with members of their class whom they selected. The audio-taped interview, conducted during school time lasted from 20 to 30 minutes. Simple classroom materials used during instruction prompted student thinking about science concepts. All interviews were conducted in work rooms near the student's classroom.

Students are identified by a four character code: (a) a letter identifies the classroom, (b) a number signifies the student within a classroom, (c) M or F identifies gender, and (d) H, M, or L identifies academic achievement level of this student as judged by the teacher. For instance, J4MH identifies Jenks' classroom, student #4, male, and ranked as "high" in academic achievement. Analysis of all transcripts were completed before teacher rankings were known by the researchers.

The interviews were organized around topics chosen by the teachers as those most closely aligned with the content of project inservice activities. During planning meetings with each teacher, through phone calls, and electronic mail conversations, each teacher outlined specific aspects of content around which we designed the interview questions. There was no external validation of the interview content nor external check for the reliability of interview protocol. The interview format was piloted during year 1 of the ISC project that provided the practice necessary for reliable delivery of target questions and follow-up probes. We observed at least one class and one video tape taught by each teacher on the science topic of the student interview. These observations were compared with descriptions of teaching practice and statements of belief collected in teacher interviews. These observations also facilitated understanding the nature of content as seen by students. The teachers also discussed materials used during instruction from which we selected prompts for each set of interviews.

Results

Transcripts of teacher interviews along with direct and video taped observations of teaching were used to characterize each teacher's view of constructivist teaching and to describe teaching practice. Discrepancies between teacher description and observed practice are noted and discussed. Interview data established instructional objectives for the segment of instruction that formed the basis for direct observations. Each teacher was required to select one of the topics from the summer workshops and include it the curriculum the following year. Interview data from selected students were used to assess the extent to which the teacher met stated objectives.

Ms. Jenks, Grade 7

View of Constructivist Teaching. Jenks treats student ideas and student talk with a high degree of respect. She believes it is important to generate student ideas about a topic before formally teaching in order to structure further instruction and to foster student thinking. Student expression is encouraged throughout instruction by varying instructional strategies and providing opportunities for student expression. She also recognizes limitations in divergent teaching strategies.

> I would say my class, what I think what I wish would happen doesn't always happen....see what kinds of things they know, sometimes, we do a warm-up thing every day where they have a couple of questions that sort of settle them when they come in, they have something to do. Some of those are review from what we've done before, but as I go into a new unit I often use them to just see where they're thinking, and it's definitely a group picture. I use that, and it really only gets those people who will respond.

She described how she employs text-based material and worksheets to explicitly instruct students on a particular topic. She feels that this is a comfortable and secure mode for some students and for those who are not responding, this is one way of getting some response to specific content. Time- and energy-intensive forms of constructivist practice must also be balanced by text-based, explicit forms of teaching as a fall-back position just to survive the job from day to day.

Teaching Objectives. As part of a broader, year long emphasis on form and function, students were expected to describe the relationship between form and function in bird beaks, wings, and feet. Students were also expected to speculate on the function of natural and manufactured objects based on personally generated analogies to the appearance or form of the objects. For instance, while holding a piece of tree fungus, students were expected to generate an analogy of form (e.g. It looks like a thick leaf) and speculate about its function based on that analogy.

Teaching Practice. Ms. Jenks is an active teacher. She moves throughout the room of 35 students interacting with the class even when the presentation is based on an overhead transparency. Observed methods included open-ended questions for which she would try to get multiple responses. Student ideas were solicited by an opening activity designed to probe their current knowledge. During one observation, students were asked to draw their favorite bird as a prelude to a discussion of form and function of different parts of bird anatomy. While it was not clear just what previous knowledge they would draw upon to recall the features of a favorite bird, it was clear that students were exercising their general knowledge of bird appearance. This was followed by direct observation of bird feathers using a jeweler's loop and one of two microscopes. Students were prompted for specific observations. She kept the pace of classes quick to fit the schedule and student interest thus limiting the number of students who could respond to any one point. She worked at bringing closure to lessons sometimes at the expense of dispensing with the investigative thread of instruction and conducting a review of specific observations or main points.

Student Knowledge. Each student protocol was assessed by a rubric that treated each follow-up question as an additional prompt. The fewer prompts needed to stimulate discussion relevant to the current content topic in the interview the higher the student was evaluated. The same rubric was applied to the George interviews in that the content and grade levels were the same. The rubric for the content portion of the protocol was as follows:

1. High - Student mentioned both structures and functions in birds in at least two contexts with only the initial question as a prompt.

2. Medium - Student tended to mention functions only with references to structures included only after specific verbal prompting. Combined references to structures and functions after prompting would not be sufficient to warrant a "high" rating unless the references were in at least two completely different contexts.

3. Low - Student tended to mention functions only with minimal references to structures included only after specific verbal prompting. A response was judged minimal when it appeared to repeat hint provided in the prompting questions.

Two students out of the six interviewed in Jenks class were ranked "high" in knowledge because they readily linked structure and function without the need for specific prompting. The student whose response is used for this sample discussed structure and function 10 times during his interview. In this response, he discusses a class activity that asked students to relate the structure of household tools with the function of bird beaks.

J2MM: The beak shapes, there's we had a station thing where one, there's like a thing full of water with Styrofoam and they had to use like three different kind of things to see which one was the best used. It was like the strainer because it could just pick it right up out of the water and the water would go up.

In this next sample, he comments on the wings, feet, and beak of predator birds in pictures presented during the interview (see Figures 1 & 2). The one named as a "tarnagan" is being attacked by a hawk (see Figure 1).

J2MM: Ya. It looks like it should be like a quick flyer and it's got talons so it can like pick up things pretty easy. It's four–toed and there's a toe in the back so it can pick it up. It's a good ripper, so it's a meat eater. The one right next to it looks like it's a tarnagan or anything like that. It looks like it should be a quick take–off because they get into trouble with other larger birds and it looks like it walks around on it's feet because it doesn't look like it has strong toes. It's only got three it looks like. It must just walk around usually unless it's attacked.

The next example is the only student out of six interviews that was ranked "low" in student knowledge. Note that she recalled the key phrase from the instruction: "form follows function." However, beyond the first statement, she was only able to relate form to function with prompting. She also had considerable trouble generating descriptive language for other parts of the bird. Note also by the "H" designation on her identifier that she was selected as a representative as a "high" achieving student by the teacher.

J5FH: Well we talked about form follows function, about how their beaks are formed for what they eat, and owls to rip and tear flesh, like little mice and stuff.

I: … tell me about the birds in this picture, just by what you can see?

J5FH: They look like they hunt very well. Their claws look like they crush the animal. They fly down and grab it and kill it. And their beaks look like they could rip it very well.

I: What in particular about the beaks that make you think that?

J5FH: They're kind of hooked. The top are. And also their feathers are very sleek so he can fly very fast.

I: Any differences between the one of the left and the one on the right…?

…

J5FH: This one looks a little bigger, tail feather… Their head shapes look a little different.

I: And how different? In what ways?

J5FH: Well like that … just like um , that one looks smaller.

When asked to comment on a selection of materials used in class to generate discussion about structure and function, she had trouble commenting on anything other than what the item looked like.

J5FH: Well like this is part of a bee hive, like the honey comb part, dried up and stuff.

J5FH: Pine cone. (Prompt) Yeah it feeds birds, these little things on it, they pick out and stuff.

Mr. George, Grade 7

View of Constructivist Teaching. George's classroom is populated with live animals, such as two foot iguana, large boa constrictor, rabbits, and guinea pigs. These animals did not play a direct role in any of the observed lessons, but students were highly interested in their presence. The animals are expression George's belief that children should be physically and emotionally connected to what they study.

> A room without animals to me would just I can't imagine what it would be like. Because they are kids, that's just an automatic connectedness. …When they say wow, this is not a classroom, this is a zoo ya know, well that makes me feel good. That means this is a place where they would like to come. …On the other hand you have the negatives if the iguana

> says he's gonna go to the bathroom when you really feel like you're …really working…that stops. You have to wait so the animals can take the class away from you anytime they want, it's there.

George feels a tension between opening the class to questioning and exploration and guiding students in their work. Students have opportunities to express their ideas but the science content forms the structure of the class.

> I'm doing this constructivist thing where I'm starting to see where-they start from and I try to build on that. Once we get going on that I guess the main things that I try to do that I feel are important, first of all I feel reading and the content area in science is far different than the reading they do in other areas. I try to teach them the tricks early on of how to do that, of how to read slowly. Then I do a lot of concept and nature mapping. …I do a lot of that and as far as introducing material, sometimes we read it, sometimes we brain storm it.

When asked if he involved students in helping plan the content of lessons his reply was: "…I'll give them choices sometimes and the problem with that is it's hard to direct their learning when they don't know the choices." He feels strongly that students should be expressing what they know and what they want to know. He has developed some specific practices that now form routines for eliciting their ideas. These were in place before the ISC project but have been treated somewhat differently in his attempt to focus on student ideas. Through concept mapping, students should understand that there are numerous ways information can be organized and should appreciate points of view offered by other students.

Teaching Objectives. George used the topic of form and function of bird beaks, wings, and feet as part of a larger unit on the study of wetlands. Using observations and data collected from a field trip to a local wetland area, students were expected to create four or more classes from the 50 species of birds observed on the wetlands trip. The basis for the groupings was to be based on function. They then had to identify a common set of wings, feet, and beaks for each group. Their final product was to be a mind-map or poster that showed a classification of wetland birds with a description of what they do (function) and drawings of common wings, beaks, and feet that are in each function group (form).

Teaching Practice. A typical class opens with a warm-up question on the overhead, for instance, What is a wetland? What features does it have? Students take notes and a brief discussion follows. The notes go into their notebooks for future reference and for use in mind mapping exercises. The main activity is connected to the warm-up questions by a statement such as, "We will be working on a concept of wetland." In the observed lesson he discussed the difference between your 'concept' of wetland and a dictionary definition. "Yours is more lengthy and will change to accept new information. You will construct a concept like building a house. You know in general about a house but not what a construction worker knows. Some of your ideas are misconceptions."

A brainstorming activity involved two student note takers at two chalkboards alternately writing down each idea presented by the class. In this case they were getting ready to go on the wetlands field trip. George distributed legal sized sheets of paper with a category marked at each end. "What you know" was on left and "What you want to know" was on right. In the middle students developed a concept or "mind" map. The brainstorming procedure lasted nearly 15 minutes and became very repetitive. When students finished their list of what they knew about wetlands and were asked for what they want to know many of the same points showed up only this time they are stated as questions. For example, students knew that there are many different kinds of birds in wetland areas but wanted to know what kinds of birds they were. He allowed this process to proceed completely unmediated. A mind mapping activity that occurred on a different day employed a long list of topics generated from the brainstorm. Classroom observations of students notes showed that listed items for what they knew and what they want to know often look the same. George moved around the room actively engaging students in brief discussion about their maps and prodding several to include more information.

Student Knowledge. Students saw many examples of birds through the wetlands study. This student exhibited a "high" level of knowledge based on the rubric discussed above for Jenks.

He easily related structure and function through recall of a humming bird example as well as by observing the pictures of a hawk and falcon used as prompts for the interview.

> G5MH: For instance, like the hummingbird, if I saw a beak that was real long, slender, that type of thing, I'd figure it was meant for poking into holes or something and getting food from there.
>
> …
>
> G5MH: Well this one here looks like a hawk and it's got the long talons and the sharp beak with the curve on it. You can tell that it'll eat other animals and other birds.
>
> …
>
> G5MH: That the bird is designed for catching and ripping up and eating prey. You can also tell by the build of the bird that it's used for soaring and it's able to fly long distances.

Three students were ranked "low" mainly as a result of minimal response. It was difficult to tell whether this was from low motivation or lack of understanding. The first example is a response to comparing the hawk and falcon pictures (see Figures 1 & 2).

> I: I'm gonna ask you to look at a couple pictures. By looking at these birds, could you tell me something about what they do?
>
> G6FH: They fly, they have wings and there are lots of kinds of birds.
>
> I: …If you look at them like their beaks or their wings or their feet, can you assume something about how it lives, what it does?
>
> G6FH: Like if a bird has like–we did this activity in class and we had to–we used like nets and chopsticks to see how birds–what kind of birds has which beaks and what it does. I don't really know much about like what it does.
>
> I: …if you looked at this beak, would that beak suggest anything in particular about what this bird is able to do or what it does in it's life?
>
> G6FH: I have no idea.
>
> I: Okay, anything about the feet? Have you looked at its feet here?
>
> G6FH: Maybe they catch little insects, or maybe the climb, I don't know.

In this second example, the student would not respond to the questions in terms of structure and function but seemed to be trying to identify the names of each bird.

> I: If you looked at a bird and just by looking at say it's beak, it's wing, could you tell me something about that bird even if you didn't know the bird?
>
> G7FM: I don't know, I could probably take a guess at it, but it'd probably take me a long time to actually understand what the bird is.
>
> I: …by examining these, what could you tell me about these birds just by looking at their pictures?
>
> G7FM: These look like they're feisty and they look like somewhat colorful. I don't know if I've seen that bird before. It's gray, brown and white. These birds over here, this looks like a hawk. It has some…, gray, brown, and white.
>
> …
>
> G7FM: Lets see, this is kind of like water, close over here some type of seagull.
>
> …
>
> G7FM: I guess if I had studied birds more then I would tell. This one by the way it's head goes and it's pointed it looks like a hawk. The seagulls have big eyes and that's why I was guessing this one.

Mr. Davidson, Grade 5

View of Constructivist Teaching. Davidson expressed a sincere interest in helping students explore a topic based on their own developing knowledge. However, his view suggests that a constructivist teacher does not give information to students. Rather, the teacher helps students ask questions and guides their activity toward obtaining an answer. This generated concern that there was no way to assess what students were learning other than by listening to their questions and observing their activity. The following excerpt captures the essence of Davidson's perspective.

> Well I see myself not telling the facts, not giving them information only as a springboard to question. I think that was the basic difference in what I was teaching before and how I was teaching. …What I really liked about the constructive point of view was to let the kids kind

> of lead in their questioning and then going and creating a curriculum about what their questions were. I like that approach because then they are involved. Then you're taking what they're interested in and what their questions are and trying to create an atmosphere where they can find out on their own. So there's a lot of things I resisted. One thing I resisted was the open-endedness of no closure on a lesson. It bothered me for a long time this year. There's no closure, there's no way of testing this, there's no other way of knowing other than just by what the kids are saying.... So that required me to really redo a lot of testing approach, how do I know.

The omission of closure and withholding information did not represent the intent of the ISC workshops. However, discussion with project staff suggested that this point of view does had some basis in experience if one is overly focused on the personal knowledge construction philosophy behind the demonstrated teaching practices.

Teaching Objectives. Davidson's teaching objectives were quite consistent with his view of teaching. "Students will learn the importance of observation by drawing a picture of what they think a snail looks like and one picture of actually observing the snail. Students will learn to keep records by recording observations in a snail folder and tracking speed of snail on at least 3 runs. Students will learn to write down in the folder habits of the snail (eating, types of food, mating, speed of snail - all habits)." These lesson objectives were supplemented with notes on the nature of science and constructing reality (e.g. "observing and questioning, hypothesizing - reconstructing reality, making meaningful connections with whys and hows").

Teaching Practice. Davidson exhibits the warmth of a father-figure during his instruction. Slow to anger and with a smooth voice, he conducts an informal class with clear expectations for student behavior. His science instruction was modeled almost completely after the activities presented in the ISC workshops. Instruction was typically organized around the process of observing and producing written descriptions. He begins a science class by having students write down questions they have as a result of thinking about the topic from previous lessons.

> We will be making new observations that you have never made before. Write down questions about snails. ...We don't know anything about the inside of a snail - write questions about inside of a snail.

After students retrieved their snails, a common teaching behavior was to circulate around the room and prompt students to write down their observations. He reinforced this activity by probing students for what kinds of questions they had, in this case about snails, and repeating questions or observations he considered to be interesting to the entire class. The entire class participated in these sessions with few exceptions. Davidson used specific reminders about appropriate behaviors and occasionally moved or separated students to maintain order.

Student Knowledge. Each element of Davidson's science teaching appeared to stand on its own and to be largely derived from the ISC project. The rubric for assessing student understanding of snails was derived from reading of the entire set of 10 interviews. Transcripts were coded for the following components in the snail topic derived from discussions with Davidson, classroom observations, and class handouts: Reproduction, Eating, Digestion/Defecation, Movement, Sensing, Shell, and Structure/Function. The rubric was:

1. High - Expressed correct information about snails as judged against the class handouts. They offered observational support where appropriate that was not clouded by preconceived notions.

2. Medium - Expressed some correct information but also included misconceptions based on preconceived ideas or from incorrect interpretations of observations. Specific prompting was needed to generate ideas in some component topics.

3. Low - Student could not clearly respond to prompting questions. These students tended to be those that had little to say.

Students ranked high in their understanding of snails were able to respond with elaborated answers with very little prompting. This group included 4 of the 10 interviews. This student gave specific information that was supported by observations.

> I: I see. Tell me about these things sticking out in the front.

D1MM: These are tentacles. I think there's eyes on them. We're actually not even sure that they see or have eyes. Then we think these smaller ones on the bottom are feelers that feel things if something goes wrong. That's why it comes in when it touches things.

The "high" students generally verbalized more than those ranked lower. Those with more to say also had more substance to say. In this example, talks about the shell and about reproduction. This girl expresses a misconception that was mentioned by seven of the 10 students interviewed in Davidson's class. With students ranking lower, this misconception figured more prominently in the discourse. The misconception was that baby snails would crawl into the "female" snail to keep warm and moist and then crawl out. This appeared to be an integration of the correct idea that the shell served to keep the snail moist and that snails lay eggs out a small opening near the head. However, students pointed to the large and visible respiratory pore as the place where young took refuge. This misconception will be noted in future examples as well as this one.

I: What's the shell for?

D2FM: Protection. There's a hole there. It could be for a number of reasons, but I know it's inside of that one cuz mine–I don't want to get into that. I think it might breathe out of it. Sometimes the babies will go in to keep warm. The shell also helps it to keep moist so it's not all dried up.

I: So the snails have babies, what's that look like?

D2FM: They're eggs.

I: What happens when they have the eggs?

D2FM: They're both male, and they're both female, they have both organs, but they need somebody else to mate. When they mate they have tubes that go into each other and that's how they mate. When they lay the eggs I don't know where the eggs come out of and so what happens– it took ours about a week until they hatched and then they have small shells and they're really tiny and they (...) shells from the ocean and they eat it and it helps their shells get stronger. It's harder for them to keep warm, so that's why they go into the shell.

This response was elaborate and essentially correct with the exception of the misconception as noted. It appears that most of the unobservable information that students picked up came from a set of handouts.

The one student ranked as "low" was full of misinformation and had to be prompted for it. The first part of the response states the misconception about baby snails but with a twist that makes the snail more like a marsupial. Additional example of misinformation follow.

> D3ML: Well I learned that instead of snails pooping out of where they usually poop, they poop out of their side ya know. They go to the bathroom at the side. Me and my friends think there's a hold in the snail right here where the babies go in there and when they're old enough to come out and they're hungry they come out and eat and the mom goes over to it and it kind of runs the snail over cuz it happened when we were doing this, and the baby was born.
>
> I: (Because of the above comment about the "mom" snail) How can you tell the mom snails from the dad snails?
>
> D3ML: The mom snails have a lighter shell, so this one seems like a girl probably cuz it has like a light shell.
>
> I: Tell me something about the parts of the snail. What's the shell for?
>
> D3ML: It's for what they sleep in. I don't know that much about it. They sleep in the shell, the shell is actually for the baby to stay in.

Mr. Lesh, Grade 6

View of Constructivist Teaching. Lesh expressed a tension between opening the class to questioning and exploration and guiding students in their work. Lesh is energetic and interacts with a large number of students during each class. There is often a sense of urgency in his questioning as though there is a specific point to be made that is just around the corner. The following excerpt describes the source of the urgency in terms of efficiency. The reference to the invention of writing concerns a unit on archeology.

> I think that-it's hard to do but I'm working on it, is valuing all points of view, especially the ones you know are misconceptions or inaccurate and acknowledging that that's good and I'm glad you're thinking and trying to credit (the student with) that thinking and at the same time you want to say, but hey writing wasn't invented for another three million years. …I like to put kids in a problem solving kind of situation and then ask them, how do you want to collect the data, how do you want to display it?… The teacher in me wants to plan and structure and organize because it's more efficient and it's more predictable. I would like to do more of allowing kids to plan their own things.

Lesh is reflective and can see his instruction from various perspectives. He related his broad goals for developing inquiry and expression of student ideas to the variations he perceives in the dynamics of each class. Constructivist practices are mediated by what engages students quickly and effectively. If giving explicit instructions sets a task on a productive course, then he is in favor of doing that. He easily reflects on what is gained when a task is less structured and what is lost when explicitness replaces exploration. It is clear that he is happy to reduce the amount of rummaging and foraging that accompanies less structured work.

Teaching Objectives. Lesh taught students about the nature of science through the use of "pet" rocks as a prop for analyzing, classifying, and as a means of raising questions. Students were to see science as a way to express tentative ideas about how the world works based on replicable information collected directly from experience. Scientists create these ideas by engaging in a variety of investigative processes (e.g. observing, classifying, predicting, data collection, communicating, measurement, experimenting, hypothesizing, applying math skills). Science is a body of knowledge created by people as a result of these investigations, but it is knowledge that changes as more investigations are conducted. Some knowledge is found to be incorrect, some is altered and some knowledge is considered new.

Teaching Practice. Lesh is a high energy teacher who interacts with many students each class period. His practice can be characterized by the effective use of management routines that serve to remind students of specific procedures and behaviors. When taking notes on a video, students were quickly reminded about clearing their desks and having the appropriate materials available. All students were ready within a few seconds. During a discussion on the importance of questions in scientific investigations, Lesh moved throughout the room as he fielded comments. He responded to each comment making wait-time II usually less than one second. Activities are conducted with similar energy and interaction. Students were asked to examine groups of "pet" rocks for patterns that could be used to classify them. Lesh visited all parts of the room providing verbal feedback and carrying a familiar clip board making notes on the conduct of specific groups for feedback later.

Student Knowledge. The protocol for Mr. Lesh's students was organized around four areas: (a) Practice and processes of science, (b) Fallibility of scientists, (c) Validation and proof in the practice of science, and (d) Respect for science and scientists. The rubric closely parallels the content rubric by distinguishing medium from high students based on the need for prompting and the eventual coherence or relatedness of the response. Low students usually lacked sufficient response to place them in the medium category.

1. High - Using only the initial question as a prompt, the student was able discuss processes of science (e.g. observing, inferring, data collection, analyzing, etc.), fallibility of scientific knowledge based on at least a variable interpretation of data, production of new ideas at least based on specific activities of a scientist designed to generate new ideas (e.g. making new observations, studying, talking with other scientists) as opposed to vague references to "thinking" or "guessing."

2. Medium - Student was able to produce acceptable responses to the categories in the "high" ranking after specific verbal prompting.

3. Low - Student was generally unable to produce responses to scientific activity that was distinguishable from the direct influence of verbal prompts.

Student responses were either stimulated by recalling the classroom activity of caring for and describing a "pet rock" or by pictures of science-related activities. When asked What do scientists do? the following were typical responses:

L1FM: Science is kind of like how things are, how things work. That's basically what we kind of talked about with these rocks; how they are formed, what they are. So we kind of talked about the main science things about these rocks.

L2MH: Well, science is just sort of the learning of different things and we were learning about different things like the-what kind of rocks there are and how to tell what they are.

While most students related science to finding things out, some described the experimenting and investigative processes more explicitly. Describing the work of scientists outside of classroom examples was always vague and suggested that students had difficulty imagining or at least expressing the work of scientists. The following responses related classroom activities with rocks to the actual practice of science.

L2MH: They do different experiments that would prove that they were like metamorphic or igneous or whatever. Like dropping acid on them and if they bubbled, they would probably be igneous.

Students were consistent in saying that scientists were fallible and their work could turn out to be wrong. They also found this aspect of science to be reasonable, that is, it was OK for scientists to be wrong and still be good scientists.

I: What do you suppose would happen if (another scientist studied) the rocks (and) came to different conclusions about what they thought was true, what would happen?

L3FM: They'd probably go back and do it again. If they came to different things and they disagreed, they'd probably go back and do it again.

I: Is it possible that they might continue to disagree about it?

L3FM: Mm hmm (yes).

I: What do you suppose might be necessary to resolve the problem?

L3FM: To work together and then they can do both the things on it together so they can see if they were doing something wrong you could see what they were doing.

The general position on how scientists respond to being wrong or finding some information to be incorrect, was to describe scientists studying something in more detail and gather more information.

L4MH: They guess and check and then they go around to like other scientists and see what they got and see what's like similar. They like go around to other people.

I: …Is it possible that with all that activity they may never know?

L4MH: Ya.

I: In other words just wouldn't ever be conclusive about how old the rock is or what it was made of exactly?

L4MH: They could be close but I don't now if they could be super exact, but maybe sometimes they could.

I: What would make it possible or is it possible to be super exact?

L4MH: Ya, cause with the technology we have today like microscopes and like identifying the minerals and what kind of rock it is and comparing it to other rocks it could be super exact.

I: If you had a scientist or a team of scientists that did… a lot of checking and a lot of testing and so on,… and say ten years later another scientist or a group of scientists did similar studies… and they said that the first group was wrong even though the first group felt that they were being super exact. Would that be possible to happen, and if so, why?

L4MH: Ya, because technology could improve, like a long time ago they thought the earth was flat and they thought they were super right and it turned out they were super wrong.

These students believed that scientists improve in their ability to gather more and better information through improved technology, the involvement of more scientists, and studying something over long periods of time. They did not express an understanding that science can advance based on new ideas or theories that make new investigations possible.

Discussion

The data presented is primarily anecdotal. The teacher interview data is reliable to the extent that the two different interviewers who asked similar questions about views of teaching and instructional objectives generated similar results. That was generally true. The validity of one set of teacher interviews rests on how well the protocol represents the categories of the CLES and in turn how well the CLES represents what is generally held to be a constructivist learning environment. Statements of validity in this area are problematic. First there was no expert assessment concerning validity of the protocol with respect to the CLES. The guide for designing the interview is shown in Figure 1. Second, given the data in this study, there is some difficulty in establishing what constitutes a constructivist learning environment. There is a degree of internal validity in the student interview data in that the authors reached agreement with each teacher on the appropriateness of questions that probed what was being taught. There was also discussion among the authors and ISC project directors concerning the validity between what the teachers were teaching and what was presented in summer workshops.

Insert Figure 1 about here

Even with the above caveats, together these four profiles of teaching beliefs and behaviors provide descriptions that prove serviceable in making testable statements about constructivist-based, inquiry-oriented teaching. The data present a wide variety of teaching practices while at the same time presenting a remarkably similar picture of teacher beliefs. These teachers affirmed the value of student expression and student thinking contributing to the conduct of instruction.

> Jenks: …what I think what I wish would happen doesn't always happen….see what kinds of things they know.
>
> George: …but I guess it's some way to get the information out and then I do a lot of mind mapping.

Davidson: …to let the kids kind of lead in their questioning and then going and creating a curriculum about what their questions were.

Lesh: …valuing all points of view, especially the ones you know are misconceptions or inaccurate and acknowledging that that's good and I'm glad you're thinking and trying to credit (the student with) that thinking.

The overall sense of "constructivism" that comes from these teachers trades more on the metaphor of "building lives" than "constructing knowledge." This softer view of constructivism translates easily into statements about the significance of student ideas in learning. However, it is difficult to observe the role these ideas have during instruction beyond the teacher providing an opportunity for students to express them. Davidson seemed the most purposeful in probing students for ideas then looking for ways build the curriculum from them. But his approach lacked closure in two ways. It lacked the closure of summarizing content and reinforcing important scientific ideas. He spoke of this problem erroneously as being an intended part of constructivist teaching. His teaching also lacked closure around the specific meaning and value of student ideas in his curriculum. Their ideas never received the criticism that ideas, taken seriously, deserve. Consequently we are left wondering how Davidson and the other teachers perceived the role of all this student talk. Should student statements be recorded, assessed, and criticized? Should students be expected to generate and express ideas or may they opt out and merely participate in discussion at a non-specific level?

Even though the teachers seemed to have a common understanding of what we have called a "soft" version of constructivism, they had widely differing views of what it meant to practice constructivist teaching. Both George and Lesh developed instructional routines prior to ISC workshops that were employed to bring out student thinking, structure group interaction for sharing ideas, and promote connections to learning outside the classroom. This contrasted with the more open teaching styles of Jenks and Davidson. Their goal was to generate a free flow of ideas that allowed for all kinds of observations in Davidson's room and the generation of analogy and metaphor in Jenks' room. This contrast raises a question about the meaning of process in a constructivist classroom. It was hard to find the content of subject matter in Davidson's room. It was in a sense all process. Some might say that Davidson opted for a form of non-teaching in science by letting his students raise questions and record information without comment. Assessment was based on the completion of notes and drawings. Jenks on the other hand expected her students to be able to note and draw specific differences in the form and function of bird beaks, wings, and feet. Is constructivist practice open to both forms of teaching? If both are valid forms of constructivist teaching then how are they related during instruction? How are teachers to address both explicit knowledge goals emphasized by both George and Lesh and still promote inquiry and the construction of knowledge?

Student knowledge was assessed after the fact with no "pre-test" comparison. It is entirely possible that whatever Davidson's students said about snails or Jenks' and George's students said about birds was understood before instruction began. However, there was a consistency across student knowledge in each class that clearly pointed to common experiences and some common understandings that would not have arrived intact across all students. Experience, about which students talked clearly, took the form of whole class discussions, group interactions, and hands-on activities. From the teacher-selected sample of each class (see Table 2), students demonstrated knowledge that was consistent with what the teachers said they were trying to teach. This was demonstrated by Davidson's students in their highly descriptive discussion of how they observed and experimented with their snails. They also shared a remarkable misconception about reproduction and care of offspring that was promulgated around the room. This is consistent with Davidson's position of not providing information, an admittedly perverse interpretation of science teaching. Students of Jenks and George were not only able to recall specific activities concerning, for example, the classification of birds (George) or the generation of analogies (Jenks) but also apply knowledge of form and function to pictures of birds they had not seen before.

Teachers selected students who represented a cross section of achievement in their classrooms. The students represented that cross section but not always as the teachers expected. Of 23 interviews, there were 14 discrepancies between teacher ranking of student achievement and rankings based on assessment of student interviews. In two cases, rankings based on interviews placed a student ranked "high" by the teacher in the low knowledge category and in one case a student ranked "low" by the teacher was placed in the high knowledge category. But whether our ranking would hold up under replication or not, the overall picture was that students from each class demonstrated knowledge consistent with teaching objectives presented in a teacher-defined, constructivist learning environment.

Implications for Teaching and Further Research

Given the variety of teaching practices exhibited by these four teachers, there are no easily synthesized implications for teaching. Interview data concerning instructional objectives and teacher beliefs, observations of teaching practice, and assessment of student knowledge reinforces the impact of specific instructional objectives that are in concert with teacher beliefs. The disparity between Davidson's objectives and those of the other teachers highlights two related questions for further research. What are ways of stating instructional objectives that are best met by constructivist teaching practices? And this question begs the second: What are specific operationalized forms of constructivist practice? Research in this direction will require what Reigeluth (1983) called prescriptive instructional design theory. Such a theory deduces instructional methods from a given set of instructional goals and conditions. Constructivist theory has typically been used to explain student learning in clinical settings or in specially arranged classroom instruction. As such, discussion of learning theory and instructional design theory has been commingled in research reports. Data from this study suggests that constructivist theory as applied to instruction needs to spawn an instructional theory explicit enough to deduce specific methods that in turn can be tested in classrooms.

Elsewhere one of the authors has argued for a theory of "dynamic adaptation of instruction" that recognizes learner capabilities vary within and among individuals and that the goals of instruction change even within the context of a unit or lesson (Flick, 1996). Teachers in this study were experienced and demonstrated capabilities in adapting instruction to a variety of students. What we may have observed in these widely varying teaching practices was a common set of ideas about constructivist theory being adapted dynamically in response to a number of classroom variables. Some of these variables are well known and well studied such as developmental capabilities and prior achievement of students. Others may be more subtle and less understood such as the character and social dynamics of an entire class or the pace and nature of instruction adjusted for both local and global conditions.

A short list of implications for research on teaching and teacher education might include:

1. Analyze instruction by skilled teachers for how objectives for both explicit knowledge and inquiry or higher-order thinking are met.

2. Operationalize constructivist-based, inquiry-oriented objectives, for example in terms of observations of student activity or student discourse.

3. Expand understanding of assessment so that it can accommodate the nature and purposes of constructivist-based, inquiry-oriented instruction.

4. Explicitly address the relationships that exist between selecting activities and identifying learning objectives. An objective can be met by a variety of activities and an activity can meet a variety of learning objectives.

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Table 1

Teacher use of constructivist teaching practices ranked by total CLES scores

Teacher	Gender	Grade Level	Instructional Topic	Rank based on Observations	CLES Rank (score) July 1995
Jenks	female	7	Form & Function in birds	Medium	130
Davidson	male	5	Snails	Low	128
Lesh	male	6	Nature of Science	Medium	121
George	male	7	Form & Function in birds	Medium	98

Table 2

Number of interviews by classroom and gender

Teacher (grade level)	Boys	Girls	Total
Jenks (7)	3	3	6
Davidson (5)	7	3	10
Lesh (6)	3	4	7
George (7)	4	3	7
Total	17	13	30

The interview protocol focusing on instruction	Sample Items from: Constructivist Learning Environment Survey * Science Teaching Efficacy Beliefs Instrument
• What are some typical things that go on in your science class?	
Relevance of Instruction	
• Is it OK to ask the teacher "why do we have to learn this?"	It's OK for students to ask me "why do I have to learn this?" Its OK for students to complain about activities that are confusing.
Teacher Actions	
• What does your teacher do that helps you learn science?	* I am typically able to answer students' science questions. * I generally teach science ineffectively.
Expressing Ideas	
• Do you ever discuss your own ideas in class and tell the teacher what you are thinking? • What does the teacher do when you express your ideas? • Does this help you learn about the activity?	It's OK for students to express their opinions. It's OK for students to stick up for their rights. It's OK for students to question the way I am teaching.
Peer Discussion	
• Do you ever talk to other students about science during science class? • Do you learn some things from other students when you talk to them during class? • Do you learn as much from other students as you do when you talk or listen to the teacher? • Anything else about science and science class that you want to talk about that we have not mentioned?	Students get the chance to talk to other students. Students explain their ideas to other students. Students ask other students to explain their ideas.

Figure 1. Design of teacher interview protocol matched questions with selected items in the Constructivist Learning Environment Survey.

THE MARYLAND COLLABORATIVE FOR TEACHER PREPARATION: MAKING SENSE OF THE ENACTMENT OF REFORM IN THE PREPARATION OF SPECIALIST TEACHERS OF MATHEMATICS AND SCIENCE

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Abstract

The Maryland Collaborative for Teacher Preparation (MCTP) is a National Science Foundation (NSF) funded statewide undergraduate program for students who plan to become specialist mathematics and science upper elementary or middle level teachers. Higher education institutions involved in this project include the majority of higher education institutions within the Maryland System responsible for teacher preparation, including community college representation. In addition, several large public school districts are active partners. The primary goal of the MCTP is to promote the development of professional teachers who are confident teaching mathematics and science using technology, who can make connections between and among the disciplines, and who can provide an exciting and challenging learning environment for students of diverse backgrounds.

This paper presents a reflection on the research conducted in a longitudinal, multi-level, multi-dimensional research program charged with documenting and interpreting the development and implementation of a NSF funded, statewide teacher preparation program in mathematics and science education. The intent of the reflection is to contribute toward the researchers' sense making as the research program enters its fourth year of operation. It is also offered as a case study of research from which interested readers may gain insights to assist in their research efforts in diverse contexts. Reflections relate to the decisions and actions made in the following areas: the

research team; the research design; the research instruments; the data collection; and the data analysis. A call for internal support of research efforts within NSF and other funded mathematics and science teacher preparation projects is made to support knowledge growth in this critical realm.

Background

The Maryland Collaborative for Teacher Preparation (MCTP) is a National Science Foundation (NSF) funded statewide undergraduate program for students who plan to become specialist mathematics and science upper elementary or middle level teachers. Teacher candidates selected to participate in the MCTP program are, in general, representative of all teacher candidates in elementary teacher preparation programs in academic ability. MCTP teacher candidates are distinctive, however, by expressing and interest in teaching mathematics and science. Recruitment efforts have attracted many students traditionally underserved in the teaching force, most notably African Americans to the MCTP.

Higher education institutions involved in this project include the majority of higher education institutions within the Maryland System responsible for teacher preparation. Several community colleges also participate. In addition, large public school districts are active partners. The goal of the MCTP is to promote the development of professional teachers who are competent to teach mathematics *and* science using technology, who can make connections between and among the disciplines, and who can provide an exciting and challenging learning environment for students of diverse backgrounds. This goal is in accord with the educational practice reforms advocated by the major professional mathematics and science education communities (see, for example, National Council of Teachers of Mathematics (NCTM), 1991; American Association for the Advancement of Science (AAAS), 1993; National Research Council (NRC) of the National Academy of Sciences, 1996).

The MCTP was funded in 1993 for up to a five year period to create teacher education programs that contain:

- Specially designed courses in science and mathematics, taught by instructors committed to a hands-on, minds-on interdisciplinary approach.

- Internship experiences with research opportunities in business, industrial and scientific settings, and with teaching activities in science centers, zoos, and other institutions.
- Field experiences and student teaching situations with mentors devoted to the interdisciplinary approach to mathematics and science.
- Modern technologies as standard tools for planning and assessment, classroom and laboratory work, problem-solving and research
- Placement assistance and sustained support during the induction year in the teaching profession
- Financial support for qualified students.

Enactment of the Program

In practice, the MCTP undergraduate classes are typically taught by senior faculty in mathematics, science, and education who make efforts to focus on developing understanding of a few central concepts and to make connections between the sciences and between mathematics and science. In some instances doctoral students who have interned with a faculty member in an MCTP class and have expressed a ken desire to teach in a reform-based manner also teach MCTP classes. Faculty strive to infuse technology into their teaching practice, and to employ a instructional strategies recommended by the literature to be compatible with the constructivist perspective (e.g., student-centered, address conceptual change, promote reflection on changes in thinking, and stress logic and fundamental principles as opposed to memorization of unrelated facts) (see, for example, Cobb, Wood, Yackel, McNeal, 1992; Driver, 1987). Faculty lecture is diminished and student-based problem-solving is emphasized which requires cross-disciplinary mathematical and scientific applications.

The MCTP teacher candidates, selected by using criteria developed at each institution, take the reformed undergraduate mathematics, science, and education classes and have the opportunity to participate in summer internships in mathematics and science rich environments (e.g., museums, zoological parks, and private companies).

Overview of the Paper

This paper presents a reflection on the research conducted in a longitudinal, multi-level, multi-dimensional research program charged with documenting and interpreting the development and implementation of a NSF funded, statewide teacher preparation program in mathematics and science education. The intent of the reflection is to contribute toward the researchers' sense making as the research program enters its fourth year of operation and to offer insights which interested readers may use in their contexts. Key areas examined include:

- The research team
- The research design
- The research instruments
- The data collection
- Data analysis

A call for internal support of research in funded NSF teacher preparation projects concludes the paper. Interested readers are invited to journey to the MCTP's homepage on the internet (http://www.wam.umd.edu/~toh/MCTP.html) to obtain additional text on the MCTP Research Group's efforts (including copies of previous research reports that expand on points alluded to in this paper).

The Research Team

The MCTP project leadership, under the direction of Jim Fey, MCTP Project Director, University of Maryland, College Park (UMCP) appointed J. Randy McGinnis (science educator), UMCP, and Tad Watanabe (mathematics educator), Towson State University , to share the leadership of a Research Component of the MCTP. The guiding notion for this decision was to ensure representation of both the mathematics education and the science education research domains in the project's research program (see, McGinnis, Roth-McDuffie, Graeber, & Watanabe, 1995). This notion was extended in the selection and recruitment of the two expert research consultants to the group (Catherine Brown, mathematics education, Indiana University, and

Kenneth G. Tobin, science education, Florida State University). Anna Graeber, mathematics educator, UMCP, agreed to serve as a mentor to the Research Group.

Reflection: Balancing the research team between the mathematics and science education research domains has produced a powerful research team with a vision of teacher preparation research arising from the confluence of different research lineages bearing on the same issue, teacher preparation. A significant effect of this complementary research team is the expanded body of literature (and contact individuals within each domain) from which to seek guidance and understanding. Another significant effect is the broadened number of research forums to present and to report the group's research products (including at the annual meetings of the following research associations and in their respective journals: Association of Educators of Teachers of Science, National Association for Research in Science Teaching, National Science Teachers Association, National Council of Teachers of Mathematics, Psychology in Mathematics Education, Research Council on Diagnostic and Prescriptive Mathematics, and American Educational Research Association).

A somewhat disquieting realization which has also come as a result of this collaboration in mathematics and science education research has been how difficult it is under even the best of conditions to broaden one's identity soley as a "science education researcher" or a "mathematics education researcher" to create a new research identity that includes another discipline. We define ourselves in specialized educational research communities in which we were enculterated and we can readily envision; we resist replacing those images of ourselves with more expansive identities that we create through the process of research collaboration with the 'other.' Currently there is no formally established research community of mathematics and science educators to support this identity change. Even if there were, would we be able to participate in it along with our previous research community responsibilites? These are unresolved issues we ponder in times of reflection. On a positive note, the experience of collaborative research offers the unique benefit of challenging us to reflect on what are the similarities and differences between our research communities. This leds us to better understand ourselves, each other, and educational research in general.

The Research Design

In essence, the primary purpose of research in the MCTP is directed at knowledge growth in undergraduate mathematics and science teacher education. The unique elements of the MCTP (particularly the instruction of mathematical and scientific concepts and reasoning methods in undergraduate content *and* methods courses that model the practice of active, interdisciplinary teaching) are being documented and interpreted from two foci: the perspectives of the faculty and the teacher candidate. The research design is longitudinal, extending throughout the entire four-year undergraduate teacher education preparation program and the first induction year of the MCTP specialist teachers. Also, since the scope of the MCTP program is statewide, the design of the research is multi-level (state, higher education institution, and individual). And finally, since the researchers composing the MCTP Research Group are diverse in research discipline backgrounds (mathematics education and science education) it is multi-dimensional (both faculty and teacher candidates serve as layers of interpretation, and both research domains (mathematics and science education are investigated) are documented and interpreted. Implementation of all components of the research design are contingent upon the research questions crafted for the program.

The following questions served as the *a priori* research questions that were presented to the National Science Foundation in the MCTP grant proposal:

1. What is the nature of the faculty and teacher candidates' beliefs and attitudes concerning the nature of mathematics and science, the interdisciplinary teaching and learning of mathematics and science to diverse groups (both on the higher education and upper elementary and middle level), and the use of technology in teaching and learning mathematics and science?
2. Do the faculty and teacher candidates perceive the instruction in the MCTP as responsive to prior knowledge, addressing conceptual change, establishing connections among disciplines, incorporating technology, promoting reflection on changes in thinking, stressing logic and fundamental principles as opposed to memorization of unconnected

facts, and modeling the kind of teaching/learning they would like to see on the upper elementary, middle level?

Upon NSF funding, some additional first-year research questions emerged:

(1) Does the integration of mathematics and science content and pedagogical preparation in their college teacher preparation program lead to curricular integration of those subjects in teaching opportunities by the specialist teacher candidates?

(2) Does the strengthened content and pedagogical preparation of the specialist teacher candidates help them to focus instruction on student conceptual growth, rather than factual and procedural learning? Also, does it prepare them to make deeper assessments of the learner's thinking and to choose instructional responses from an array of options?

(3) Do the science and informal education experiences assist the specialist teacher candidates in engaging learners in authentic learning investigations? Do they provide them with pedagogical knowledge and resources for meaningful motivation of students?

Reflection: These research questions have served the MCTP Research Group as identifiable landmarks in a sea of collected data as the research program has progressed over the last three and a half years. While valuing and employing a liberating and creative "emergent and contingent" research *modus operandi* (K.G. Tobin, personal communication, November 10, 1995), the early conceptualization of a limited number of research questions within the MCTP Research Group has been useful. The initial research conceptualization has assisted us in focusing on clear targets upon which to direct our energies and upon which our efforts can be evaluated. This has not restricted our interest in equally worthwhile emergent research inquires such as investigating the process of faculty transformation. It has, however, established a core referent upon which we all feel responsible to contribute.

The Research Instruments

Crafting instruments to assist in collecting relevant data that promise to inform the key research questions was the first step. It required extensive energy from the MCTP Research Group. Developing a valid and reliable questionnaire to measure teacher candidates' attitudes and beliefs toward mathematics and science and about the teaching of those disciplines became necessary once an exhaustive review of the literature did not identify any one extant instrument which had that focus or could efficiently do so within a 15-minute time constraint (a constraint insisted upon by the project leadership). The final 48-item instrument took two years to develop in order to ensure its validity and reliability as a research tool. It is named *Attitudes and Beliefs about the Nature of and the Teaching of Mathematics and Science* and is especially appropriate for use with prospective teachers of mathematics and science (see, e.g., McGinnis, Shama, Graeber, & Watanabe, 1997a; 1997b).

Multiple interview protocols for teacher candidates and college faculty (content specialists and method specialists) also needed to be developed, peer reviewed, and field tested over the years of the research program's operation. An additional instrument to use for classroom observations was also developed and field tested before implementation. Still needed is a valid and reliable content and process assessment in mathematics and science to administer at periodic points to the MCTP teacher candidates.

Reflection: This component of the MCTP Research Group's efforts has taken everyone in the research group by surprise. The time and energy required to develop valid and reliable research instruments is enormous and an oftentimes taxing exercise in patience, both among the researchers, the participants, and the project leadership. The alternative, however, of using research instruments justifiably open to peer criticism as not being valid or reliable or not appropriate to inform the research questions is not viable within a professionally run educational research program. Hard decisions within the research group on what needs to be done, in which order, and by whom are necessary to make and can generate tensions among the collaboration of researchers. There is also the danger of losing sight of the point of the research program--to answer the research questions--and to myopically focus exclusively on the development of the research instruments as if that were the main point of the research program. The MCTP Research Group has progressed through these issues by carving the research into areas of mutual responsibility (instrument development and data collection) and areas of individual research interests (i.e., faculty discourse analysis, faculty modeling, faculty and teacher candidate case studies) with some sense of equity guiding individual time and energy expenditure. Periodic reviews of the research program by the NSF and the project leadership have also served to reorient the direction of the research group so that answering the landmark research questions remain the central focus of the research. We have learned the value of using previously developed data collection instruments and are currently searching the literature for some valid and reliable instruments to measure the mathematics and science content the teacher candidates hold when they begin their senior-level methods classes. The "Group Test of Logical Thinking" (GALT) will satisfy the need to assess science process skills (Roadrangka, Yeany, & Padilla, 1982). Readers aware of any appropriate instruments to assess mathematics and science content and mathematics process skills are requested to contact the first author of this paper.

The Data Collection

Since this was a statewide research effort, with eight institutions of higher learning participating in the project, obtaining permission to collect data and then enacting implementing strategies to collect the data also required ongoing attention and much energy. Procedures for administration of the questionnaire, the interview protocols, and collection of data artifacts also needed to be developed and approved for use by multiple committees charged with ensuring the safety of human subjects throughout the University of Maryland Higher Education System.

Reflection: Obtaining ongoing instructor cooperation to administer the project's questionnaire in MCTP classes at the beginning and at the end of each semester was essential. Sending the materials out to them from the MCTP office with an accompanying letter that emphasized the commitment the project made to engage in continuous research efforts facilitated this data collection. Interviewers to conduct teacher candidate interviews twice a semester were recruited from the pool of practicing teachers participating in the project. The NSF project's funding was essential to remunerate them for their participation and to pay for the voluminous taped data to be transcribed.

Data Analysis

Since this study employed complementary research methods (Jaeger, 1988), quantitative, qualitative, discourse analysis, and action research, data analysis in each domain was required. Each is summarized below.

Quantitative

A fundamental assumption of the MCTP is that changes in pre-secondary level mathematics and science educational practices require reform within the undergraduate mathematics and science subject matter and education classes teacher candidates take throughout their teacher preparation programs. A second assumption is that MCTP teacher candidates who take reformed undergraduate mathematics, science, and method classes that are informed by the constructivist epistemology (i.e., learners actively construct knowledge through interaction with their surroundings and experiences, and learners interpret these experiences based on prior knowledge) (see, for example, von Glasersfeld, 1987, 1990) develop more positive attitudes and beliefs toward mathematics and science and the teaching of those subjects. A third assumption is that throughout the MCTP teacher preparation programs the active collaboration among college faculty, public school personnel, and colleagues in work environments rich in mathematics and science will prepare the teacher candidates to successfully teach diverse students.

To test these assumptions, the documentation of the MCTP teacher candidates' attitudes and beliefs toward and about the learning of and the teaching of mathematics and science throughout their undergraduate years was recognized as essential to perform. In addition, since a major component of the MCTP includes a commitment to infuse technology in the teaching and learning of mathematics and science, the documentation of how this is enacted on the college-level and how this influenced the teacher candidates' attitudes and beliefs also became crucial to report. The documentation system designed includes on-going teacher candidate interviews, classroom observations, and a regularly administered instrument in all MCTP classes to all students.

Therefore, the following research questions using quantitative methodologies are being investigated:

1. Is there a difference between the MCTP teacher candidates' and the non-MCTP teacher candidates' attitude toward:

(i) mathematics and science?

(ii) the interdisciplinary teaching and learning of mathematics and science?

(iii) the use of technology in teaching and learning mathematics and science?

2. Is there a difference between the MCTP teacher candidates' and the non-MCTP teacher candidates' beliefs toward:

(i) the nature of mathematics and science?

(ii) the interdisciplinary teaching and learning of mathematics and science?

(iii) the use of technology in teaching and learning mathematics and science?

Answers to these questions are particularly relevant to two domains of widespread interest in mathematics and science teacher preparation. The first domain is in documenting what attitudes and beliefs elementary/middle level teacher candidates develop during their undergraduate college programs toward the nature of and the learning/ teaching of subject matter. This information will enable those interested in mathematics and science teacher preparation to construct more valid attitudinal and belief profiles of a typical major. With that information teacher educators will be better able to understand teacher candidates at discrete levels of their program. The second domain is in better understanding the effect of systemic effort throughout the entire undergraduate subject matter and pedagogy teacher preparation program to institute reforms advocated by current thinking in the mathematics and science professional communities. This information will enable those interested in mathematics and science teacher preparation to more accurately predict the consequences of enacting advocated reform practices.

Items for the instrument needed to measure constructs within the affective, belief, and epistemological areas to inform the research questions include: attitudes toward and beliefs about mathematics and science, interdisciplinary teaching and learning of mathematics and science, and the use of technology to teach and learn mathematics and science. Sections of the instrument that were verified by Factor Analysis dealt with beliefs about mathematics and science; attitudes toward mathematics and science; beliefs about teaching mathematics and science; attitudes toward learning to teach mathematics and science; and attitudes toward teaching mathematics and science.

The instrument includes two groups of items. One group consists of thirty-two items that are to be answered by all students. The other group consists of nine items that are to be answered only by those intending to teach. The pre-planned sub-scales were verified on each group of items separately, using principle-components factor-analysis, with varimax rotation. The reliability of each of the five sub-groups in the instrument was examined by Cronbach's alpha ($\underline{n}$ =486, α=.76). For each of the five groups, a variable X_i was defined as the mean of scores on items in the group.

Another factor that was further extracted from each of the five groups is linked to the classification of most items into pairs. Each pair included two corresponding items, one from the mathematics discipline, and the other from the science discipline. Paired items were then also examined for reliability.

Reflection

The use of this research methodology, while initially viewed as a necessary yet unexciting area of research by members of the research team, is proving to be essential in the effort to paint a landscape picture of the attitudes and beliefs of college students in Maryland (both of teacher candidates and other majors) toward the disciplines of mathematics and science and the teaching of those disciplines. In addition, the instrument development was exhaustive and rigorous and offers both the mathematics and the science education research communities a valid and reliable instrument available for use in differing contexts. However, we have learned that the crafting of a survey instrument to measure these constructs and then the analyzing of the results in a statistically valid manner requires much expertise that takes considerable time to develop. Our recommendation to other research groups is to recruit associate members to the core research team who have the specialized expertise in questionnaire development and quantitative data analysis *early* in the research program. This is a structured research strategy with highly developed rules and procedures that requires expert attention to be successful and not excessively tax the energy of the research team.

Qualitative

The interpretative research methods employed in this on-going five-year study are guided by Alasuutari (1995), Erickson (1986), and LeCompte, Millory, & Preissle (1992). The intent is to focus on "the meanings of actions, as defined by the actors' points of view " (Erickson, 1986, p.119). It is conducted within a constructivist paradigm which is guided by an associated set of ontological, epistemological, and methodological beliefs (Guba & Lincoln, 1989). Namely, as investigators, we assume that there are multiple realities which can be socially constructed, ours would be but one. And, we believe that our findings will be knowledge claims or constructions which we negotiate among ourselves by using the data we collected in the setting in which we worked.

Data are currently being analyzed throughout the study by the principal investigators and doctoral education students. The analysis and interpretation process consists of reading and examining collected data placed in the NUD.IST environment and formulating tentative assertions that are being negotiated among the investigators. These tentative assertions are being tested by many sources in the data set. This iterative process of phases of interpretation, critique, and reanalysis is a hermeneutic cycle that results in the emergence of joint constructions of one possible view of the intending teachers' discussion and actions during their undergraduate classes.

Preliminary analysis of the wealth of data from the first two years of this research study (there exists approximately a year's delay in the analysis of data due to the time needed to collect and then process the data into formats amenable to analysis tools and strategies) indicates that there are intriguing regularities in the participants' attitudes, beliefs, and performances. These findings are reported in depth in other research reports (see, e.g., King & McDuffie, 1996; McGinnis, Graeber, Roth-McDuffie, Huntley, & King, 1996; Roth-McDuffie, McGinnis, & Watanabe, 1996; Watanabe, McGinnis, & Huntley, 1996; Watanabe, McGinnis, & Roth-McDuffie, 1997). In addition, several manuscripts based on these findings are under review for journal publication in the *Journal of Research in Science Teaching*, the *Journal for Research in Mathematics Education*, and *School Science and Mathematics*.

Reflection:

The use of this research methodology has been particularly effective in providing the researchers with participant voices from throughout the project. These voices are used to construct a coherent story of the project in general to share with those interested in this NSF teacher preparation project. The voices are also used in case studies of individual faculty members and college students participating in the project. Themes of how the faculty perceive each other's role in teacher preparation, how they perceive making connections between mathematics and science, what constraints they see in implementing courses that emphasize connections between mathematics and science, and how individual faculty members and teacher candidates perceive the enactment of MCTP reforms are some of the analytical constructs that have emerged.

These stories, while cogently telling the MCTP story, have also produced some tensions within the Research Group and within the project. The selection of case study individuals is difficult. Should only the "success" stories be told or should also the less than ideal situations be documented and interpreted? Who gives permission to being revealed among peers as a teacher in need of assistance in a teacher preparation program, less than successful in implementing the project's reforms? What researcher desires to have colleagues unhappy with their depiction in a case study? How can the researchers resist the prevailing hope of the project leadership that this project will be successful? Insisting upon the use of pseudonyms for faculty to protect the confidentiality of them and their students strikes some as unnecessary, even counter to their goal of being recognized by their peers, yet needs to be done. These are some of the salient issues which must be expected to arise in research projects of this scope. Maintaining a vision of conducting oneself as an ethically bound professional researcher oftentimes is the only guidance one has in these matters, as insufficient as that may sound, or feel, in particular situations.

Discourse

Discourse as used in this study is defined as the dynamic interplay of dialogue between individuals that includes the use of rules developed by certain groups of people (Gee, 1990). The focus on discourse in this study is the result of recent theoretical views that stress the importance of the context in which members of a community communicate (Greeno, 1991; Rogoff, 1990; Roth & Tobin, 1996). Conversations, or `talk,' is recognized as a particularly revealing resource in analyzing social interactions for patterns of sense-making in a community (Lemke, 1990; McCarthy, 1994). The assumption made is that this form of analysis particularly will assist in understanding the college teaching faculty's beliefs and actions taken in designing and teaching undergraduate teacher preparatory science classes in which connections between mathematics and science is a major goal. Research in teacher beliefs and actions have been a major focus of teacher education research since Clark and Peterson (1986) and Munby (1986) alerted the research community to its importance in understanding teaching practice.

In the MCTP, the large speech community consists of college faculty members who teach revised mathematics and science undergraduate content classes at universities, colleges, and community colleges in Maryland. Mathematics and science content expertise and an expressed interest in reforming content classes for MCTP teacher candidates define the criteria membership in the teaching faculty speech community. Sharing ideas on the role of mathematics and science in MCTP undergraduate content is a conversation referent. In each of these speech, or discourse communities there are two groups: discipline content experts (termed 'mathematician or science content specialists' by the conversants in this study's speech community) and pedagogy content experts (termed 'mathematics or science methods specialists' by the conversants in this study's speech community) (see, McGinnis & Watanabe, 1996).

Reflection

The use of this research methodology has assisted the researchers in conceptualizing the components of the community which defines the MCTP. It is used to visualize the discourse landscape college mathematics and science teachers inhabit when the referent in their thinking is science and mathematics, two disciplines the MCTP project hopes to connect. A similar analysis is currently being conducted focusing on the college student participants. Researchers should be prepared for individual members from discourse communites to disagree with statements made by other members of the same discourse community. This can elict much heated discussion if a member check is performed in a group setting, since it reveals the diversity of thought within a group that defines itself as a community. Some members may even question the validity of the data since not all members of the discourse community may be present to acknowledge their statements. It is therefore recommended to other research groups to emphasize to the participants that the intent of the discourse anaylsis is to document commonalities and differences within a discourse community. The goal of the research is not to promote a single voice for the discourse community. However, the process of documenting the voices within a community and the sharing of those voices with the members may lead some within the discourse community to pursue this goal.

Action Research

Action research is also being conducted within this project. Research on practice by practitioners is termed action research (LeCompte, Millroy, & Preissle, 1992), classroom research (Stenhouse, 1975), practical enquiry (Richardson, 1994), or teacher-research (Fleischer, 1995). Its primary goal is to promote a self-reflective analysis that can improve teaching practice. Action research as used in this study is guided by the tenets advocated by Collins (1995) and Gore and Zeicher (1991). It proceeds in a cycle of four steps: planning, enacting, observing the plan, and reflection.

Several MCTP professors of education are investigating their own teaching practices of MCTP candidates (see, e.g., Watanabe & Kinach, 1997). Since these studies involve an in-depth examination of a phenomena, they will be reported as case studies (Stake, 1995). The case study methodology enables the researchers to develop an in-depth story which provides a framework from which other teacher researchers can reflect on their experiences and which can inform future research (Romberg, 1992).

Reflection

It is anticipated that this research methodology will add a strong emic flavor to the program. The primary focus of these studies is to document and interpret the methods professors' innovation in practices guided by the goals of the MCTP. MCTP mathematics and science methods specialists with expertise in action research are ideally suited to conducted these studies of teaching practice innovation. However, these studies once again require the researchers to face difficult ethical questions. How can one who is intimately involved with the project avoid the bias of depicting their personal teaching experiences as a success? How can one whose identity in the project is based on expertise in teaching practice seem to be less than successful in implementing the project's reforms? How comfortable is it to comment on the preparation of the project's teacher candidates if they are not found to be positively impacted by the project influenced subject matter courses? Acknowledging these tensions by recruiting a co-researcher who is not a member of the project to assist with the action research study is one way we have found to guard against these biases. Finally, an important question that has emerged is some apparent conflict between the roles of the MCTP professor and the MCTP researcher. As a researcher, the professor wants to suspend judgment and mull over events occurring in the classroom; however, in many cases, as a professor he has to make an immediate judgment so that the classroom activities can continue. How does this conflict impact the 'naturalness' of the professor's instruction? Other research groups should also anticipate these type of issues and consider actions they can take to maintain the integrity of their research effort.

Conclusion

This paper presents compelling evidence that the MCTP Research Group has been active in carrying out a needed research program in a NSF funded mathematics and science teacher education project. It also presents some of the research team's learning in practice. Currently there are a dearth of reports on the process of conducting research within these large-scale teacher education projects. While conducting research within the MCTP project, the researchers have oftentimes collaborated with individuals representing other NSF Collaboratives and funded teacher enhancement projects. Surprisingly, the MCTP is distinguished among its peer projects in its organizational chart by including an internal Research Group and by budgeting ongoing financial support for its operation. This ongoing funding, no more than 4% of the project's 6 million dollar funding, has enabled this project to develop a research program that is actively contributing to the knowledge base on teacher education in mathematics and science. The research products from the Research Group will serve as one of the lasting legacies of the MCTP. This strongly suggests that the MCTP's model of a NSF funded project supporting research within itself is a viable model that calls for replication throughout the NSF and other funding agencies, particularly in critical areas such as mathematics and science teacher preparation projects.

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TEACHING THE NATURE OF SCIENCE IN A COLLEGE EARTH SCIENCE CLASS DESIGNED FOR PRESERVICE ELEMENTARY AND MIDDLE SCHOOL TEACHERS

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The recent National Science standards emphasize that the training of preservice teachers include a component that leads to an understanding of the nature of science, and that can be translated into classroom practice (AAAS, 1989, 1994; NRC, 1996). This paper describes the pedagogic underpinnings of three exercises designed to impart the flavor of scientific inquiry into an Earth science course designed for preservice elementary and middle school teachers and details how the nature of science is taught from an Earth systems perspective.

As part of an ongoing effort at Wright State University to simultaneously reform both K-12 education and the training of preservice teachers a suite of new courses were developed in 1995 and 1996 that would teach the science domain content that elementary and middle school teachers need to know, and model a variety of strategies and methods for teaching and learning science. A Foundations course that integrates mathematics and methods for investigating science was designed so students would come to the courses in Physics, Chemistry, Earth science and Biology with the fundamental skills necessary to pursue scientific investigations. Then these skills are enhanced in each of the four content courses.

GL-345 Concepts in Geology deals with Geology, Oceanography, the Atmosphere, and Earth's place in space. Modules within the course are centered around rocks and minerals, the rock cycle, geologic time and fossils, the water cycle, and weather and climate. It is taught with a maximum of 24 students per section, and meets for six hours per week. There is a lab component for each major topic within each module, and topics are chosen from National science content standards and National Science Teacher

Association standards. For further details of the content of the course see Slattery (1996a).

The Exercises

Three exercises designed to reveal the nature of scientific inquiry are discussed in this section. The mechanics of two of the exercises have been described in Slattery (1996b and c). What follows is a brief description of the salient details of the exercises, followed by a discussion of the ramifications of the exercises for preservice elementary and middle school teachers.

"The Box"

The quarter begins with this cooperative group exercise The activity is a variation of the familiar mystery box. Cooperative groups of three students are given a small cardboard mailing box containing four Hershey Kisses Hugs. students working in groups are asked to:

- make an educated guess about what is in the box before they get it
- manipulate the box and make observations to determine how many objects are in the box, the shape of the objects, and the composition of the objects
- discuss as a group if the observations led them to change their minds about what they thought was in the box before they got it
- decide what technology would have made their task easier

Discussion

This exercise is, on its face, uncomplicated. Based on the size of the box (size here) students know that there are a multitude of objects that cannot be inside, but there are just as many different objects that could be. The only limit is of course, size. Students are able to make the observations needed to determine that there is more than one object in the box. Initially, they perceive that the objects in the box are of different shapes, based on hearing sliding and rolling within the box. These observations cause them to change their original guess about what was in the box. Since this is an Earth science class, they usually think there is a rock in the box before they get it, and upon handling the box realize that the weight of the box precludes this. However, some cling to the belief that the box contains rocks, suggesting that perhaps I am engaging them in a discrepant event by placing a low specific gravity rock such as pumice in the box. What the groups have done in scientific terms up to this point is to form a working hypothesis, tested that working hypothesis by making specific observations, and then have amended the hypothesis based on their observations. Students rarely make the connection to the scientific terminology at this point, and I don't tell them until the exercise is completed. Class discussion revolves around the number of objects each group thinks is in the box, and the size and shape of the objects. Now it is time for the paradigm shift. Up to this point, most groups have not smelled the box, and if they did, most are unable to smell anything other than cardboard. If no group has already done so, I ask each group to vigorously shake the box for about ten seconds and then smell it. Usually, at least one, and sometimes several groups declare that they smell chocolate. This, I point out, is sometimes how scientific advances are made. Scientists will perform a novel experiment or observation and new information will emerge. Immediately, the class has a new model for what is in the box. But, what kind of chocolate is it? Is it a Mr. Goodbar, a Hershey miniature, a Hershey Kiss? Based on their observations of sliding and rolling within the box, they use their domain specific knowledge of candy to decide that Hershey Kisses are most likely to be in the box. This is the role of concepts in science. Without specific content facts about the size and shapes of candy bars, they would have difficulty progressing past this point. Fortunately though, their prior experiences with candy enable them to mentally scroll through the various candy shapes and come up with the most likely candidate. Technology such as CAT scans and X-rays are suggested as methods to corroborate their findings. This too, is an accurate scientific analogy, as models in science become stronger as different lines of evidence triangulate upon them. However, all the technology suggested cannot answer the question of the color of the wrappers. Are they the traditional silver, or pastel colors for the Spring Holidays, red and green for Winter, or are they striped? Some questions must wait for the advance of new technologies. A class discussion relating this exercise to the study of the Earth ensues. Students often relate the box exercise to studies of the interior of the Earth, and discuss the methods of determining the composition or and the nature of the crust, mantle and core. Some students realize that the study of the interior of the Earth can be studied by earthquake data and share this with the class. They also realize, that unlike the box, the Earth cannot be opened at the end of a scientists' experiments, so scientists are not sure about the composition and nature of the interior of our planet. We can however, use different lines of evidence to get close to what is reasonable. The collection of data is shown to be an integral part of the nature of science, and this exercise builds interest for what is to come. The next activity asks the students to collect earthquake data from the internet, and to plot that data for investigative purposes.

A Near-real Time Earthquake Activity

Preservice teachers will enter their professional careers in a far different world than their predecessors. Many classrooms will be linked to the internet and world wide web, and teachers will grapple with the challenge of using this resource for classroom instruction. Acknowledging this reality, a significant number of exercises in the Earth Science class require that the students access on-line information. The following is an example of a long term exercise (six weeks) that requires students to access on-line data and additionally allows them to understand how scientists use earthquake data to delineate tectonic plate boundaries of the Earth. Students are given a physiographic chart of the Earth, and are asked to access the United States Geological Survey's National Earthquake Information Service homepage at http://geology.usgs.gov/quake.shtml. They plot the longitude, latitude and depth of the earthquakes over a span of several weeks.

Discussion

Most, but not all earthquake activity occurs at the margin of the plates. At the end of the exercise the student has at least partially recreated the classic figure in Earth Science textbooks that shows the plate boundaries of the Earth. They have learned how scientists use data in their investigations, and most importantly, the anomalous data points within plate boundaries are the jumping off place for class discussions of topics such as the New Madrid earthquake and What if... questions, focusing on (no pun intended) the possibility of earthquakes in areas that have not been tectonically active.

The Greenhouse Effect

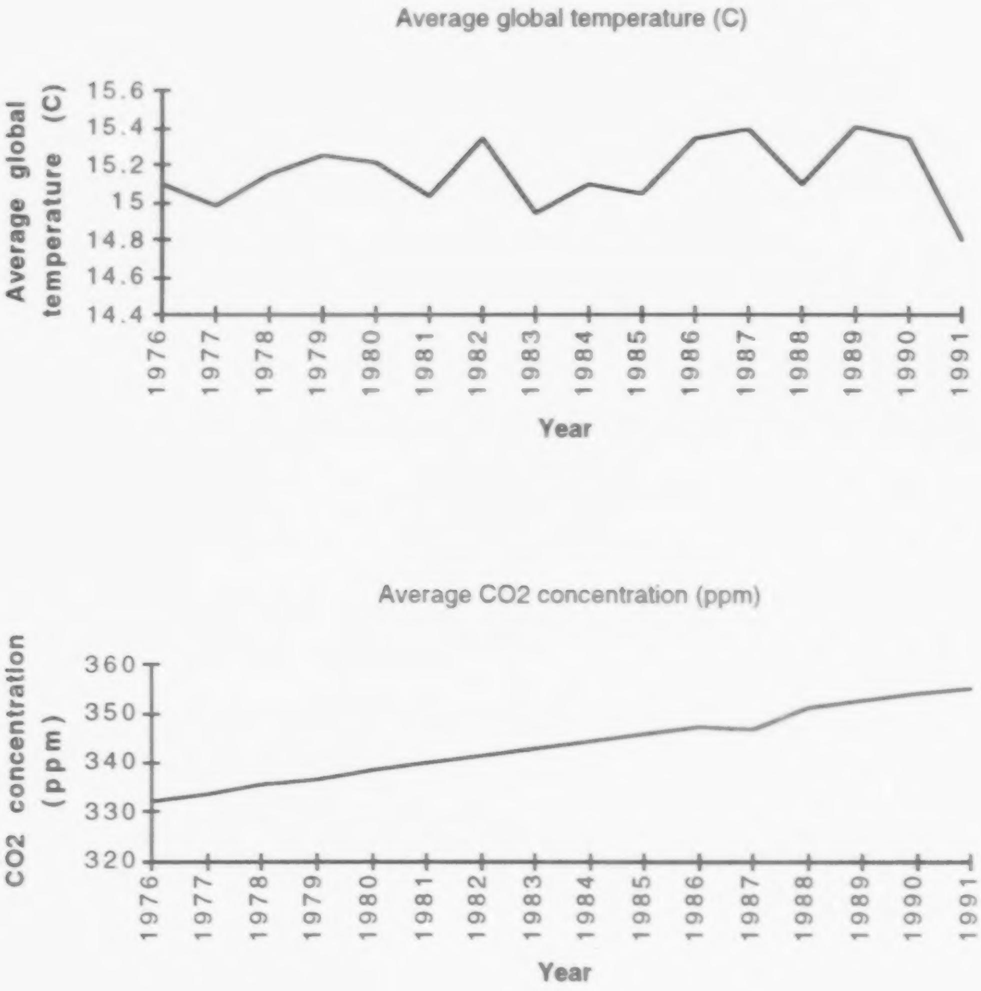
The internet/world-wide web is a largely untapped source of data that can be used to fashion exercises that expose students to elements of scientific inquiry, processing and analysis of data, and understanding that the real world is complex, with many variables interacting to produce a single measured parameter. Our class investigates the greenhouse effect during a two week period. The internet/world-wide web is essential to our investigations. Table 1 is a summary of web sites, data, and tasks that are performed on-line.

Table 1. Summary of Internet data resources for Greenhouse Effect Module

SOURCE	URL	DATA
National Oceanographic and Atmospheric Administration	http://www.ncdc.noaa.gov/gblwrmupd/images/fig2.gif	Average yearly global temperature
Carbon Dioxide Information Analysis Center	file://cdiac.esd.ornl.gov/pub/trends93/co2/maunaloa.034	average monthly and yearly carbon dioxide ppm concentrations
United States Geological Survey	http://geology.usgs.gov/quake.shtml	Near real-time earthquake data
YAHOO	http://www.yahoo.com	search for sites that have pro and con opinions regarding global warming. Also, to extend the investigation into specifics such as rain forests.

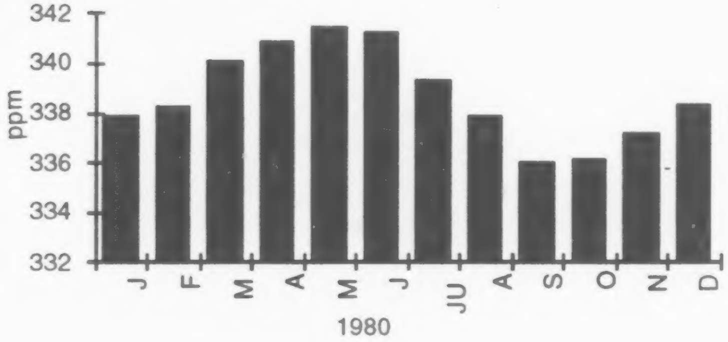
Students first download yearly average global temperatures, and average yearly atmospheric carbon dioxide concentrations in parts per million measured at the top of Mauna Loa, Hawaii. These data are plotted as a function of year in Figure 1.

Figure 1. Average carbon dioxide concentration and temperature vs. year



Students see a rise in carbon dioxide in the atmosphere, but global temperature rises and falls. There must be other factors at work, so it's on to the net. By searching web sites such as Volcano World, they see that average global temperature drops when significant volcanic eruptions occur. They discover that volcanic ash prevents some solar energy from reaching the Earth, and that this has an effect on the temperature of the Earth system. Decreases in the monthly concentration of carbon dioxide in the atmosphere during the northern hemisphere summer (see Figure 2) show students the effect of the biological draw down of carbon dioxide by deciduous trees.

Figure 2. Carbon dioxide concentrations at Mauna Loa



They begin to appreciate the interplay between the Earth's lithosphere, hydrosphere, atmosphere, and biosphere, not by lecture, but by meaningful, minds-on activities. The web is searched to find opposing viewpoints, and the module is capped by group reports on the Greenhouse effect.

Discussion

Students have heard about global warming, but few have had a chance to judiciously assess the data for themselves, increase their own knowledge of this complex societal issue, actively search for opposing viewpoints, and use what they have learned to produce a presentation based on fact, not opinion.

Conclusions

The three exercises represent different modalities of teaching and learning the nature of science in an Earth science class for preservice elementary and middle school teachers. Materials range from decidedly low tech cardboard boxes to downloading data and text from the exponentially evolving internet/world-wide web. There are however, common threads that run through all of them. The box exercise asks students to think about what might be in the box before they begin. These prior conceptions were usually influenced by rational thought processes, given the limitations of their prior knowledge. A subset (n=17) out of 104 students in six sections persisted in their belief that they were being subjected to a discrepant event. In some cases, the students could not form working hypotheses until they were assured that this wasn't the case. This may have broad implications for the use of discrepant events as a tool in science education, and bears further investigation. The amending of prior conceptions is a key element in the earthquake and global warming exercises as well. Students were surprised to see how many earthquakes didn't occur on plate boundaries, and this generated numerous questions about possible reasons. The variations in carbon dioxide concentration in the atmosphere led to discussions about the causes of these variations, and sometimes to a request for more "net time". The internet is inherently superior to archived information sources because sources can be accessed rapidly, will be used in their future classrooms, and because they like it. I cannot remember a class demanding to send a representative to the library to look something up so that a vigorous discussion of factual information could continue.

The role of domain specific content is another common thread. Clearly, it is specifically a knowledge of candy bars that is needed when the paradigm shift takes place in the box exercise. A knowledge of the names of sports teams, or for that matter the American Revolution, just won't do. Similarly, content must be domain specific in the earthquake and global warming exercises. The exercises are a vehicle for the increase of content knowledge, as well as teaching the nature of science. Students inherently understand that reality, and have eagerly sought out the content needed to bolster their arguments in the global warming exercise. To remain economically competitive tomorrow, the students of today must be comfortable with the use of technology, and be scientifically literate. Since teachers teach as they have been taught, their future classrooms are more likely to produce scientifically, and technologically literate citizens.

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ANALYZING AND USING CHILDREN'S LITERATURE TO CONNECT SCHOOL SCIENCE WITH PARENTS AND HOME

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Rationale for Involving Parents as Partners in Science Education

This year's AETS conference focus on systemic reform of science education brings attention to the role of teachers and science educators while leaving out an important partner in education reform. Parents are a crucial contributor to the education of their children and they should have a role to play in lasting reform efforts. The triad of parent, teacher and child is more efficient and effective than any of these paired.

Research advocating parental involvement is evident in the literature (Daisey & Shroyer, 1995; Riley, 1994; Rillero, 1994). The benefits to parents, students and teachers are well documented. There are multiple reasons why parents should be involved in the education of their children (Epstein, 1987; Hester, 1989; Rillero, 1994; Rutherford & Billig, 1995). Some student benefits include improved behavior, increased achievement and motivation, and lower truancy rates. Parents feel more connected to the schools and their children. Teachers gain an ally who supports their efforts. Lists of suggestions for teachers and principals to increase parental involvement abound (Epstein, 1987; Hester, 1989; Rillero, 1994). Characteristics of projects which have successfully involved parents provide a starting point. This paper describes one way to substantively involve parents in elementary science instruction. It also gives guidelines for elementary methods instructors who may want to incorporate this approach in preservice education. The method has been successfully implemented in all 16 elementary schools of a midwestern school district. From the standpoint of the teachers and parents involved, it has been successful (Chidsey & Henriques, 1996; Dunkhase, Shymansky, Dunkhase & Jones, 1996; Grohe, 1996).

Epstein (1987) suggests 16 ways to involve parents. Included on her list are:

- Ask parents to read to their children regularly or to listen to the children read aloud.

- Loan books, workbooks, and other materials to parents.
- Ask parents to get their children to talk about what they did that day in class.
- Explain to parents certain techniques for teaching, for making learning materials, or for planning lessons.
- Give a questionnaire to parents so they can evaluate their children's progress or provide some other form of feedback. (p. 8)

Hester (1989) and Rich (1988) make similar suggestions. In addition to the materials sent home and suggested activities to be done at home, they focus on increased and better communications between parents and teachers. This ought to be done via phone calls, letters, meetings at night and during the day, and through classroom visitations. While there is ample evidence supporting the parental desire to be more meaningfully involved in their children's education, few parents know how to do so and few schools systematically attack the issue (Daisey & Shroyer, 1995; Rich, 1988). These suggestions, along with guidelines for implementation are incorporated into the science bookbags discussed below.

What Is A Science Bookbag?

The science bookbags described here were designed as part of a district–university collaborative called Science: Parents, Activities and Literature (Science PALs). Science PALs is a four year teacher enhancement projected supported by the National Science Foundation and the Howard Hughes Medical Foundation. It is a collaborative effort involving all 16 elementary schools in the partner district. Science PALs is in its third year of implementation. Cadres of teachers join the project each year. The teachers go through extensive inservice programs during the summer and throughout the school year. The bookbags, put together by teams of teachers, are used at the start of a science unit to determine students pre-instruction science ideas about the unit topic.

The bookbags consist of a children's story, an activity and an interview protocol for parents and children to complete together. The bookbag, which contains complete directions for the parent, is sent home before instruction begins on a science unit. The print material, usually fiction, is selected by the teacher teams when planning the district unit, and is related to the unit, either directly or peripherally. The interview questions address ideas in the story and the child's understanding of the science concepts involved. The interviews are short, containing only four or five questions. The parent's role is to gather and record their child's ideas. After completing the interview the parent and child do an activity together, the materials for which are included in the bookbag. The entire process takes roughly 30 minutes.

The information gathered during the interview is returned to the teacher along with the book and activity materials. The books and materials are used over and over as different classes start the unit. The teacher is then able to use the gathered information to guide and inform instruction. Science educators advocate a constructivist approach to teaching (e.g. Brooks & Brooks, 1993; Driver, Guesne, & Tiberghien, 1985; Yager, 1991). There are many merits to knowing what students think prior to instruction but it is unrealistic to think that an elementary teacher has the time to interview all his/her students before beginning a lesson. When the parents partner with the teacher they are gathering valuable information that would otherwise be unrecorded in any systematic way. The data collected by parents reasonably reflects their children's scientific understandings in most cases (Chidsey & Henriques, 1995). The quality of student responses is enhanced when teachers model informal questioning techniques for parents at school-based meetings prior to use with their children.

Why a Bookbag?

While many parents feel uncomfortable with science, they do feel comfortable with the idea of reading to their child. Language arts and reading are making their way into all disciplines. Literature is accepted as a valuable vehicle for teaching all subjects, not just language arts (Hope & Small, 1993). Advocates of using literature with science argue that the integration makes learning more relevant because it puts the science in a context that is more meaningful for young students (Brainard & Wrubel, 1993; Butzow & Butzow, 1989; Gertz, Portman, & Sarquis, 1996; Hope & Small, 1993; Mayer, 1995; Ross, 1994; Staton & McCarthy, 1994a, 1994b; Wiegmann, 1996). Sending home a bookbag with a science related story and a science activity seems to be an ideal solution to the problem of involving parents in a meaningful, non threatening manner.

The parent and child do the reading, interview and activity together. The ensuing dialog provides a starting point for future science related discussions. After completing bookbags with their children, parents are more likely to ask specific science related questions of their child in the following weeks. They are also more likely to discuss science during parent-teacher conferences (Shymansky, 1996). When parents can ask specific questions about their child's day both parent and child find the discussions to be more meaningful than the traditional "how was your day at school?" questions. The bookbag provides parents with that entrée.

Creating and Using Science Bookbags in Elementary Methods Classes

Elementary methods students learn a great deal by putting together a science bookbag. Many prospective elementary teachers already have favorite children's stories but they have rarely looked at stories from the perspective of teaching science. When they begin to put together a science bookbag they are forced to look at the science unit holistically. They must decide the unit's major goals and this often requires looking to the *Standards* (NRC, 1996) or *Benchmarks* (AAAS, 1993). Students then investigate misconception literature and assess misconceptions in their chosen books. Finally, they find appropriate literature connections which enhance the science unit.

When a potential book has been found the methods student must analyze the story in terms of the science ideas presented. There is a debate as to whether the story must be scientifically accurate to warrant inclusion (Mayer, 1995; Ross, 1994). We take the stance that an inaccurate portrayal of science is an excellent starting point for instruction. When students become critical readers, questioning the ideas they see in print, they are on the way to becoming critical thinkers. When methods students look at the story from the perspective of science they begin to analyze the science ideas, ask questions and formulate potential experiments to test the ideas.

Once the book is selected and analyzed in terms of scientific content, the methods student should then look through the *Standards* (NRC, 1996) and/or *Benchmarks* (AAAS, 1993) to see what big ideas are related to those presented in the book. The major ideas of a unit ought to be derived from the accepted standards for the grade level. The most effective stories will relate to those ideas.

Misconception literature is then examined so that the teacher will have an idea what his/her future students are likely to think about the given topic. The questions that comprise the interview will tap into these commonly held student ideas. This aspect of bookbag creation allows prospective teachers to purposefully look at misconception literature, thus applying the constructivist approaches which are stressed in our classes.

Methods students then select an activity which is directly related to the story. Materials needed to do the activity are included in the bookbag along with directions for completing the activity. This phase of putting together a bookbag requires future teachers to locate an activity which could be easily and affordably done at home. As they look for an appropriate activity they are becoming familiar with the resources available to them. Clear directions for completing the activity must be written for inclusion.

Putting together a bookbag requires methods students to communicate clearly with parents in writing as well as orally. Ideally, these future teachers will be holding a parent meeting where they will explain bookbag implementation, and they will need to be comfortable communicating verbally during this time. They will also need to write clearly because it is unlikely that all parents will attend a parent's night. The directions included with the bookbag must be well-written enough to be able to stand alone.

Practically speaking, the book, activity and interview questions will be sent home together and large zippered plastic bags work well for this purpose – all the materials fit inside and they can be reused. Numbering the bags enables the teacher to keep track of which students have returned their bag after completion.

The process of putting together the bookbag synthesizes many of the skills that are desired in methods students who are about to become teachers. They must analyze the science content of a story and think about how that story will tie into the larger unit. Students must examine the commonly held misconceptions related to the topic they will be teaching and find related activities to go with the story and the unit. Ideally, they will look for activities which challenge the specific misconceptions which their students have. Finally, preservice teachers must be able to communicate well. This process gets methods students thinking about science activities as ways to engage students physically and mentally. The literature connection is a comfortable starting point for prospective teachers and activities help to create a cohesive unit.

Implementing Science Bookbags in an Elementary Classroom

An elementary teacher who would like to incorporate science bookbags into the curriculum must follow the same steps as the preservice students. It has been most effective for teachers to hold a meeting with parents prior to sending home the bookbags. The meeting provides an opportunity for the teacher to explain the bookbag and the parent's role and it allows a time for parents to ask questions. The teacher should take the time to read through the story and model the interview and activity with the parents. When explicit instructions are given to parents about interviewing and the importance of follow up questions are stressed the results are more accurate and more helpful to the teacher (Chidsey & Henriques, 1996).

Practicing teachers have several resources in addition to their school librarians to help them identify useful books. Many of the elementary science curricula include an annotated bibliography of children's books and helpful lists are included in journals and popular science magazines. For example, the March issue of *Science & Children* has a list of outstanding trade books each year, and *Scientific American* lists books for young scientists each December. There are also books devoted to linking science and literature (Brainard & Wrubel, 1993; Butzow & Butzow, 1989; Gertz & others, 1996). The teacher must look at the school's resources to determine if it is feasible to purchase a sufficient number of books so that one can be loaned to each student. Costs would be reduced if many teachers in a grade level shared the bookbag set.

The teacher must then decide if there should be a meeting with the parents to discuss the bookbags or if it would be best to simply send them home. The answer will depend, in part, upon the parental population. We have determined that attendance at the Parent Meetings can be increased when teachers couple the science bookbag meeting with another event at school. It has been our experience that parents feel more comfortable with their role when they have participated in at least one parent meeting each year. Class parents, aids or volunteers will have to read to children who do not complete the activity with an adult at home. Appendix 1 provides a checklist of steps for teachers putting together a parent meeting.

Using a children's story to get students thinking and talking about science has many benefits for students, parents and teachers. The increased discussions about science gives it more importance and value in the eyes of the student. Parents realize that they can help their children learn science. Teachers gain an ally and an aide in the learning process. The bookbags get parents meaningfully involved. Response from parents, students and teachers has been overwhelmingly positive.

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Appendix 1: Teacher Checklist For Parent Meeting to Discuss Science Bookbags.

PRIOR TO THE MEETING:

- Meet with school principal to establish date of Parent Meeting (it works well to couple this with a time parents are already at the school)
- Draft with school principal his/her letter to parents.
- Send home principal's letter **approximately 2 weeks prior to Parent Meeting.**
- Prepare and make arrangements for printing and presentation all of the print materials you want to provide to parents during the meeting.
- Select a date approximately 7 to 10 days prior to Parent Meeting to meet with room parent(s) to provide them with basic information, plans for the Parent Meeting, class list(s)(s) to aid the parent(s) in phoning each family to remind them of the Parent Meeting and to get a verbal commitment about attending the meeting. **Allow parents 3-5 days** to do the phoning and to return results to you.
- Examine the results and determine how many child care providers will be needed. Make arrangements for the provider(s), room assignment, and activities to be done during the Parent Meeting by the provider(s).
- **During the week of the Parent Meeting**, have each student prepare a personal not about the approaching Meeting and allow them to express their feelings about the program and how 'eager' they are to complete the activities which the parent(s) will be learning about during the meeting. Send notes home.
- Double-check on the materials you plan to give the parents.
- Meet with the custodial staff to discuss special set-up needs for the room where the Parent Meeting will be held.
- Make arrangements for any audio/video equipment which you desire to use during the Parent Meeting [some teachers find it useful to video tape the meeting so that the tape can be shared with parents who were unable to attend].

THE DAY OF THE MEETING:

- Day of the meeting: send home a reminder note to each family, assist/supervise the set-up of the room where the meeting will be held, call the care provider(s) with any last minute information they may need.
- put up Welcome and Directions signs to the room where child care will occur. Organize the handout materials (bookbags) in a location where parents can readily locate and bring them into the meeting room.

- Make last-minute checks on audio/video equipment which you may be using during the presentation during the Parent Meeting.
- Go home early to rest and prepare for returning to the school for the Parent Meeting.
- Return to school and check that everything is, indeed, the way you want them to be for your presentation.
- Be sure the care provider(s) have arrived and are ready to welcome the parents/children in the assigned room.
- Welcome parents as they enter school, locate their print materials and find seats in the meeting room.
- Begin meeting promptly at the time you have designated in all the communications you have had with parents.
- Relax and realize all the preparations have been worthwhile as you enthusiastically talk about your science program and the parent connections which you are seeking using the materials which you are providing to them this evening.
- Take time to thoroughly answer parent questions which may be asked during and after your presentation. Thank parents for attending the meeting.
- **At the end of the meeting**, collect all assigned materials so you'll have a record of which families were not in attendance during the Parent Meeting, thank the care provider(s) and make arrangements for compensation if that has been agreed to, and take down any posters, etc. which you want to keep for reuse.

AFTER THE MEETING:

- **The day after the Parent Meeting**: thank the custodial staff for their assistance, send thank-you's to the room parent(s) for their help in making the Parent Meetings such a success, and make similar comments to the students as you begin class that day.
- **One week after the Parent Meeting** students should be returning the bookbags and interview results. Arrange to have students read to if they did not do the activity and reading at home.
- Collate results and use the information to plan your lessons.

This checklist "Getting Started" comes for the Science PALs Project.

USING VIDEO CASE STUDIES IN PRE-SERVICE SCIENCE TEACHER EDUCATION

Marcia K. Fetters, The University of Toledo

Using case studies in rich and meaningful ways

We have all experienced days when, despite our "wonderful" lesson plans, things went poorly and we had to alter our plans and strategies mid-way through the lesson or spend time planning what we would do the next day. This is the part of teaching that is often invisible to the novice teacher. Novices don't see the alternate plans the teacher had prepared, or the thought process involved in finding different pathways to teaching various concepts. They often come to methods classes expecting instructors to share with them "the best way" to teach a topic. Sometimes students bring with them strong memories of a particular strategy that they have seen a teacher use. Rarely do recognize or accept that there are multiple strategies or ways of approaching each topic area.

Case study methods, common in medicine and law, are becoming more commonly used in education. Case materials (video and written) can provide students with practice in thinking about teaching in those ways. Several projects have developed video and or materials that were intended for (or could easily be used) in this proactive way (Martin & Marks 1995, EES/MPNE 1992, Private Universe Project 1995, NCRTL 1993, Warren & Rosebery 1994). This presentation will show some ways in which these materials can be used to help pre-service teachers think about teaching in more proactive ways.

Rationale

This method represents a departure from the ways in which case studies are commonly used. When pre-service teachers go through an education program they often read about classroom settings, watch video tapes of classroom settings, or participate in field experiences where student learning or achievement may or may not to appear to be maximized. As instructors, we ask them to analyze what they have read or seen, describe the type of learning that has occurred, and propose ideas about what lead up to those events (Sykes & Bird, 1992). In our efforts to help pre-service teachers understand the philosophies behind various reform efforts and to help them be more open to modern ways of teaching and learning, we help them develop skills in observation, analysis and reflection. These are important skills, and during field experiences and student teaching we often evaluate them on these skills. The use of casestudies for this paper focuses on using moving pre-service teachers from the critical but passive "they" stance in this analysis, towards a stance in which pre-service teachers place themselves in the situations under examination, and suggest and/or document their own preferences for teaching in a variety of situations.

Background

One of the events that prompted my thinking about using clips of classrooms in this more proactive way was by watching and listening to my students reactions when they watched classroom segments. Often they would start their comments out by saying something like: "The teacher should have.." or "If the teacher had done..." or "It didn't look like this teacher..." Comments were often critical in nature and sometimes showed that they really had not grasped the complexity of the context.

When watching a clip of a scientific discussion in a bilingual classroom the first comments from the pre-service teachers were about how rude the students were by raising their voices and talking over each other. They did not recognize this as part of an argument or that different cultures have different accepted manners of speech. They had similar reaction other times when watching video clips of classrooms. The students were very quick to say what the teacher had done wrong -- but when pressed for alternatives they had difficulty responding. This echoed a difficulty that many student teachers have -- when one strategy doesn't appear to be working, most student teachers have a difficult time thinking about alternative ways of structuring the content to help their students better understand the material. The following section highlights some of the materials that we have used with suggestions for assignments or activities. This list is not all inclusive and I'm hoping that those of us interested in exploring different uses of video casestudies can use this as the beginning of a conversation.

Strategies

The videotape that started me thinking about alternative uses when I was invited to pilot test some materials done by Doug Martin and Rick Marks. They developed a set of videotape cases in science and math as part of a National Science Foundation project. Two of the clips from the science tape "Refraction" and "Penny in a Cup" lend themselves particularly well for use in pro-active ways. The suggested questions included with the resource materials with the tape focused on teacher knowledge and student understanding. "Refraction" show a teacher explaining the concept of refraction to her students. "Penny in a Cup" is from the same classroom and documents student understanding of refraction and their ability to apply this understanding to explain why the penny appears when water is added. The student drawing and interviews show the wide variety of ideas held by the students about the nature of light. My students were quick to point out what they thought was missing from the lesson on refraction that lead to some of the misconceptions highlighted by the penny in a cup activity. The assignment for the next class session was to write a lesson plan or set of plans for the following scenario:

> *Imagine that instead of a video tape you had been an observer in the class you just saw. The school principal calls you that evening -- the teacher has just been called out of town for a few days and since you are almost certified and have been in the room observing they would like you to teach the class the next couple of days until the teacher can return. What does your lesson plan look like -- based on what you know about the current level of student understanding?*

The next class session student get in small groups and share their lesson plans. So far each time I've done this it has come as a surprise to the pre-service teachers that their lesson plans don't all look alike. Most terms there a few individuals who also talk about how they had to go back and try to think through the process of refraction themselves and try to come up with reasonable explanations.

This same scenario can be used with the video many of us use in our classes "A Private Universe." Stop the tape midway through and ask the students to design a lesson plan for how to teach the phases of the moon. They can then compare this with what Heather's teacher did. There are several clips in the new Private Universe Series that could also be used in this way. This past term I've started exploring similar uses for the "Sense Making in Science" video case studies developed my Ann Rosebery and Beth Warren (Rosebery & Warren, 1996). Elizabeth Cohen suggests similar types of questions for use with the companion tape to her book on groupwork (Cohen, 1994).

Student Feedback

Student feedback to these activities has been mostly positive. They find the task difficult, but useful. Following are some typical reactions to the assignment. These are excerpts from their class journals.

> *"Jennifer" Spring 1996*
> *I couldn't believe that I really couldn't explain the phases of the moon. When I sat down to do my lesson plan for the assignment I pulled out my old books and looked at a lot of charts. I could identify things in the book -- but I couldn't figure out how to put it into words that a student would understand. It was one of the first times that I really felt the pressure that teachers must feel every day. I knew that everyone else in the class was doing the same task and they would all catch things that I said wrong. I couldn't just sort of know it -- I had to KNOW it.*

> *"John" Fall 1996*
> *When you told us we were going to watch a tape of students learning about refraction -- I thought hey no problem this stuff I know. Unlike some of the earlier things that we did with photosynthesis. As a physics major I know optics. But when we saw all the different ideas the students had to describe the penny in a cup trick I was shocked. I would have taught the lesson just like the teacher on the tape but it was clear most of the kids didn't have a clue. It was the first time it really sunk in to me that I would have to be able to explain things in a variety of ways so that the students would understand. We've been talking about it -- but when I had to make up lesson plans to teach refraction -- it became real.*

One of the things that happened in the methods class was that no longer were the lesson plans being written just to meet my needs. Students had real ownership in the planning. In the beginning they seemed to write real generic lessons and when pressed would usually not strongly defend their choices. By using both video case studies and some examples of written case studies a context was set. The students had strong views of how and why they thought their strategies would work and by sharing those with others they also gained insight into some alternative.

During student teaching students are asked to videotape themselves twice during the term and write up an analysis of their lesson. Some of them have asked if we couldn't use their tapes in seminar and do a similar activity. They came to want the feedback and different ideas of their peers could provide.

Next Steps

I'm in the early stages of thinking about all the different ways that case studies, both written and video can be used in pre-service education and would really like to continue this dialogue with others who are trying or using them in their teaching. The attached reference list also includes a couple other sources I've used but not highlighted in this paper or presentation, and pieces that have shaped my thinking about the uses of case studies in pre-service education. I would be very interested in working with others have similar questions or in developing some rich materials for use in pre and in-service education

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THE IMPACT OF THE TEACHER RESEARCH EXPERIENCE: LEARNING "REAL" SCIENCE IN A "REAL" CONTEXT

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A old adage states, "I hear and I forget, I see and I remember, I do and I understand" (Woolnough, 1994; p.25), which seems to sum up, from a pupil's perspective, difficulties that might be associated with science learning. These difficulties have not been ignored by researchers and the science education community. Teaching science through investigation improves students' achievement, their attitudes towards science, mastery of science process skills, problem solving, and creativity (Shymansky, Kyle, & Alport, 1982). While "hands-on" activities can devolve into closed-ended recipes (Walberg, 1984), true open-ended inquiry can more closely approach the notion of "minds-on".

One difficulty for teachers that arises in the context of teaching for inquiry is that many teachers may not have experienced research or be familiar with the process of open-ended inquiry and presentation of the results of the inquiries. The National Science Education Standards (National Research Council, 1996), addresses this issue in the teaching and professional development standards. Teaching Standard A states that, "Teachers of science [should] plan an inquiry-based science program for their students" (p.30). Seemingly in response to the need of teachers to understand this, Professional Development Standard A states, "Professional development for teachers of science requires learning essential science content through the perspectives and methods of inquiry" (p.59). Thus in order to address the needs of the students for science inquiry, teachers themselves must be familiar with the process of scientific inquiry.

Over the last decade, West Virginia University, Glenville State College, and other institutions have enjoyed a relationship with the National Radio Astronomy Observatory (NRAO) in Green Bank, WV, providing research and inquiry-based experiences for inservice and preservice teachers. For the purposes of this paper, the term "institute" is used in reference to 1-2 week long residential learning experiences, held at NRAO - Green Bank. NRAO is an active research institution, serving the international astronomical community with several radio telescopes. As most science teachers are not familiar with the details and activities of radio astronomy, the institutes provide a context in which many of the participants have a common baseline of understanding to participate in inquiry without bringing along specific biases. The main goals of the institutes have been:

a) Teachers advancing their understanding of the work of scientists and experience scientific research.

b) Ensure that participants recognize their research experience as a model for learning science in the classroom

c) Assist inservice and preservice teachers in developing, implementing, and evaluating research projects for middle and high school students.

d) Assess the effect on participants doing research and using research in their classrooms in regard to understanding the nature of science, attitudes toward science teaching and toward students and teaching.

This AETS Conference session is designed to present several aspects of the institutes, from the perspectives of philosophies of science, inservice teachers' needs, and the development of preservice science teachers. A more detailed description of the goals and practices of the institutes can be found in Appendix A.

Setting and Approaches

In addressing the goals stated above, participants spent time "on location" at NRAO-Green Bank, operating a 40-foot radio telescope which has been dedicated to educational pursuits. Participants were shown the rudiments of how to operate the telescope and then given a generalized research problem. Over the course of the institute, the participants then proceed to formulate research questions, collect and analyze data, and finally present such data to the group. During this time, participants received lessons on fundamentals of radio astronomy, models of pedagogy, and how to recognize opportunities for student-oriented research during the academic year. Participants also received mentoring during the course of their investigation from resident radio astronomers and master science teachers who are familiar with the process of radio astronomy.

Once an institute is completed, participants were expected to plan, develop, implement, and evaluate a student-centered inquiry-oriented scientific investigation in their home schools. Teachers received support from their peers and project staff through class visits and periodic feedback meetings. Several participants have gone on to present their classroom projects at state and national science teachers meetings. Samples of teacher-developed research projects can be found in Appendix B.

In the third cycle of the project, preservice teachers were included in a similar process to the inservice teachers. One week prior to the start of the semester, middle grades and secondary science and methods students at West Virginia University and Glenville State College attended an abbreviated version of the inservice teacher institute. The preservice teachers represented multiple content areas in their prior coursework, but were typically seeking a general science-biology dual certification. All of these preservice teachers were taking the methods course in the upcoming semester, so participation in the institute was a part of the course requirements. About half of the participants anticipated completing their student teaching in the following semester, while the remainder still had course requirements to complete prior to student teaching.

As the institute for preservice teachers is shorter than the institute for inservice teachers (one week vs. two weeks for the inservice teachers), the science education component (i.e. pedagogy, etc.) was moved into the methods course. The emphasis for the preservice institutes was then placed on the research project participation at NRAO-Green Bank. In addition, the preservice teachers were to begin the development of their own research projects. During the methods course, the preservice teachers were expected to and received assistance in fully articulating their plans for open-ended student research projects. The description of this assignment is found in Appendix C. Critical components of this plan were the inclusion of the research project within the secondary science curriculum. as referenced by the West Virginia Science Curriculum Framework or the National Science Education Standards, the identification of variables, research questions, and a 10-day sketch plan for implementation.

The plans developed by the preservice teachers were intended to be implemented within their student teaching placement. This implementation was with the support of project staff and their student teaching supervisor, and with the cooperation of their supervising teacher. Every attempt was made to place the student teachers with cooperating teachers that had attended the inservice institute. The preservice teachers received support in the form of project development and design, equipment needs and observation and data recording. Difficulties in implementation that have been identified and dealt with have been: (1) reconciling the project plan within the place in the curriculum that the student teachers find themselves, and (2) the cooperating teacher was unfamiliar with the process of the research project and skeptical of the implementation. Current efforts to improve the project implementation by the preservice teachers have targeted these impediments.

Results

Well over 300 inservice and nearly 100 preservice teachers have participated in the institutes since their inception. A total of 32 states have been represented. Periodic contact with the participants have yielded data that underscore the positive effects of the programs. Evaluation data was originally restricted to qualitative sources, such as self-report journals, concept maps, etc. While these lent much insight to the process of research concept development, they did not provide us with evidence of substantive pre-post institute change. Therefore, we resolved to use more quantitvative measurements in the third phase of the institutes.

The literature was reviewed for instrumentation that might be useful for evaluating the program. While we found some limited instrumentation, we were not able to find the kind of measurement coverage we sought. Once major concepts representing the institutes were identified, specific indicators of each concept were then identified and thus translated into items. Items were grouped into instruments and critiqued by program staff. A battery of eight (8) instruments were put together. Five of these are discussed here: Institute Evaluation (IE), Research Self Assessment (RSA), Implementation of a Research Project (IRP), Nature of Science and Science Teaching (NSST), and Student Attitude Toward Science (SATS). Reliability analyses were done on eight groups of RETP participants (n=60) from 1994-1996 and an outside group of 200 teachers from the West Virginia Science Teachers Association. The SATS was tested with a group of 200 West Virginia middle and high school students. The remaining three instruments are still under development and testing.

The IE calls for teachers to evaluate the quality of the program, the value of the research experiences, and the degree to which the program experiences have prepared them to implement the research process in their classroom. The RSA was designed to assess the research skills, attitudes and confidence of the teachers. The IRP assesses the kinds of concerns teachers might have about implementing the research process in their classroom as well as the degree to which individual teachers hold concerns about implementing the research process. The NSST assesses the degree to which teachers hold constructivist orientation toward science and science teaching. The SATS assesses students' orientation to science, science classes, and their perceptions of what happens in their classroom.

Among the inservice teachers (n=34), 89% have reported more student involvement in investigations, 87% have reported allowing students to design their own investigations, 78% reported that concepts are explored in more depth, and 75% report that they use a variety of ways to evaluate student performance, such as through project presentations and portfolios. Many of the participants reported that they will move away from "cookbook" science instruction, emulate the processes of science and action of scientists, and they feel empowered to actively conduct research.

The preservice component, while much newer than the inservice component, has yielded similar results. The preservice teachers (n=26) were all students that were scheduled to take a science methods course in the following semester, prior to student teaching. Data were analyzed using PC-SAS. Preliminary results of one- and two-way ANOVAs (at the time of writing) indicate that there was a significant change in how preservice teachers view their capacity to conduct scientific research ($p<0.05$), and their attitudes towards science and science teaching ($p<0.01$). The results also showed that while there was no significant change in their concerns about implementing a research project in the classroom, they were not overly concerned about implementing a project in the first place. On the evaluation of the experience, the preservice participants rated the institute between 3.3 and 3.6 on a 1-4 scale. Journals kept by the students revealed that while initially they were apprehensive about the experience in general they expressed more confidence in themselves as researchers. This confidence has extended into the classroom as they participated in student teaching.

Conclusions

Overall, it appears that the goals of the program were being and are continuing to be met by both the preservice and inservice teachers. Based on the success of the program, future proposed projects will involve K-12 teachers linked to systemic reform efforts nationwide. Also under development are plans to involve high school teachers and students in international astronomical research involving the Green Bank Interferometer at NRAO-Green Bank. It is evident that learning science in the context of scientific research has empowered teachers to feel confident in their abilities to allow students to construct real and personal understandings of science. Given these enhanced capacities, the historical incongruence between "school" science and "real" science may diminish more rapidly.

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Appendix A. Project Goals and Institute Components

1. **Teachers advancing their understanding of the work of scientists and experience scientific research.**

   - Gain first-hand experience in conducting scientific research by using a 40-ft radio telescope. Report finding to, colleagues, mentors, and NRAO personnel through a scientific colloquium.
   - Work in cooperative groups and with mentors, scientists and engineers.
   - Discuss with staff and visiting scientists on how they do research or support research.
   - Become aware of the role of technology in scientific exploration.
   - Explore scientific and social issues related to research.
   - Develop an awareness of the diverse and international nature of science.

2. **Ensure that participants recognize their research experience as a model for learning science in the classroom.**

   - Discuss the components of their research experience with each other, science educators and scientists.
   - Discuss how learning occurred through doing research with other participants, science educators, and NRAO personnel.
   - Develop models for teaching science in classrooms which contain essential elements of research that they have been using in their research

3. **Assist inservice and preservice teachers in developing, implementing, and evaluating research projects for middle and high school students.**

   - Develop research problems/questions related to the science(s) that one teaches that can be investigated by middle or high school students.
   - Implement the use of research as a way of coming to know in classrooms.
   - Assess changes in students understanding of the nature of science, use of processes of science, attitudes toward science and achievement.

4. **Assess the effects on participants doing research and using research in their classrooms in regard to understanding the nature of science, attitudes toward teaching science and toward students, and teaching.**

   - Develop and field test quantitative and qualitative assessment instruments.
   - Determine short and long term changes in teaching practices, in attitudes toward science and the teaching of science, and understanding of science.

MAJOR INSTITUTE COMPONENTS

The research and science education components complement each other.

RESEARCH COMPONENT

- **Research problems**

--Element of the unknown: If one knows the solution, "answer", a research experience is impossible.

--Understanding the problem statement: Questions to consider may include what is given, what is known and unknown, what questions arise, and what are ways to approach the problem.

--Use of cooperative learning groups: Groups are made up of participants who teach in different fields of science and who teach at different grade levels (across disciplines and levels).

--Mentoring: Each group has a scientist and a teacher who previously participated in the institute as mentors who keep questions before the groups, encourage group members to work together, and make certain that each member of the group knows how to use the telescope.

--Data collection, recording, and interpretation: Participants are encourage to get as far as they are able with their problem solving and are ask to take particular note of the processes they are using and activities in which they are engaged.

--Presentation of results: Each group reports on their results with emphasis on the meaning and questions left for further research.

- **Use of the facility**

--Facility: Participants are invited to make NRAO their home for two weeks.

--Tours : Tours of the entire facility, such as the telescopes, cryogenics lab, machine shop, electronics labs, laser test range, are conducted and participants are invited to return as need or questions arise.

--40-ft telescope: A brief introduction to and practice session on how to use the 40-ft telescope is given for each group.

- **Fundamentals of astronomy and electronics**

--Astronomy: Seven sessions of activities, discussions, and lectures provide updated astronomy and radio astronomy information.

--Electronics: Background in electronics and how a radio telescope works is presented.

--Enrichment lectures and discussions: Astronomers share their approaches to science and their current research activities.

SCIENCE EDUCATION COMPONENT

- **Changing thought**
  - --Modern to post modern thought
  - --Developmental or evolutionary constructivism
  - --National and state reform movements
  - --Learning cycles, analogies, wait time, cooperative learning
  - --Assessment alternatives
  - --Applications/changes in teaching

- **Nature of science**
  - --Descriptors of science
  - --Scientific content, processes, and attitudes
  - --Relationship between the nature of science and the teaching of science

- **Use of models in teaching**
  - --Electromagnetic spectrum charts are used to compare radio waves with other waves of the spectrum to provide background for research in radio astronomy and as a way of using models to involve learners in gathering information and developing questions.
  - --What information can be gathered from the em spectrum? (Work in pairs.)
  - --What questions arise from the information on the chart? Share information and questions.
  - --Discussion of ways participants used models in their teaching and suggestions of models that could be used.

- **Fact versus interpretation/inference**
  - --Use data collected previously with the 40-ft telescope to help develop background for working with data collected with the 40-ft telescope.
  - --In groups of three or four, answer the question, What do you notice on the chart recording?. Keep a list.
  - --Decide which items on your lists are facts, information that everyone can see, and which are interpretations/inferences.
  - --Discussion on how do you help students to recognize data and separate it from interpretations/inferences.

- **Representation of data and meaning development**
  - --Simple analogy for collection of data with a radio telescope: Using the probe find ways to represent unknown objects in a closed box.
  - --Variety of data representation: 3-d models of data, contour models, false color imaging, . . .

- **Characteristics of research problem statements and design of research problems for use in classroom**
  - --Development of characteristics of research problems.
  - --Design of research problems for use with students at various levels and in the different science disciplines.

- **Sharing of research problem and revising them**

POST INSTITUTE

INSERVICE TEACHERS

- **Research projects in schools**
  - --Plan, develop, and implement two research projects in schools.
  - --Assess change in student attitudes toward and views of science. Use **Student Attitude Toward Science**.
  - --Keep a personal journal as research projects are implemented in the classroom. Reflect on changes in self and reactions to use of research in the classroom, as well as student changes and reactions.

- **Workshops/Presentations**
  - --Give workshops on research for teachers, boards of education, businesses, . . .
  - --Send in workshop record sheets

- **Feedback meetings**
  - --Sharing of research implementation activities and workshop activities

PRESERVICE TEACHERS

--Continue to develop pedagogy for implementing research in the classroom
--Plan, develop, and implement a research project in the classroom during student teaching.
--Attend the feedback meeting

EVALUATION

- **Instrument development**
  - --Research Self Assessment
  - --Nature of Science and Science Teaching
  - --Implementation of Research Project
  - --Institute Evaluation
  - --Student Attitude Toward Science
  - --Professional Activities
  - -- Observation of Student Research Projects
  - --Supervisor Evaluation
- **Journal analysis and interviews**

Appendix B. Sample Research Problems from Institute Participants

Devise a way of tracking a lightning storm and determining its relative size, speed, and direction without using satellite imagery, radar, or any equipment not directly accessible to you.

Design a means to determine how dusty your town is.

Determine which ornamental plants are easiest or most difficult to maintain in your area.

Taking into account the geologic, social, and physical environment of you area, determine the best and worst places to situate an oil tank farm.

How do the characteristics of local ponds determine the rate at which they freeze or thaw?

Design ways to determine the effect of shade trees adjacent to houses on the residents' energy consumption.

Develop a method for determining the weight of a fly or mosquito, without harming the insect.

Our eyes are adapted to a peak wavelength of 550 nm or yellow light. What would we see if we were at the following locations: M-class star, O-class star, and neutron star?

A friend from Tasmania writes to you wanting to know exactly where you live, but she just cannot find you on the map. Devise a way, in a letter, to give her your position using the sky.

Appendix C. Project Description for Preservice Science Teachers

(d) Plan for a student-centered investigation (15%): In order for pupils to gain an appreciation and intrinsic understanding of science, it is imperative for them to participate in the processes of science. For this assignment, you are asked to prepare a plan for a long-term (at least 2-week duration) open-ended investigation. This plan, which should not exceed 4 double spaced typed pages, should reflect the potential for eventual use in your classroom. This plan should include the following: (a) Description of the content or subject to be investigated by the pupils (b) Discussion of how the plan is aligned with extant curricula and curriculum reform documents, (c) An analysis of openness of the problem under investigation, (d) Thinking schedules, tables of variables, or other structures designed to assist the pupils, and (e) Daily schedule sketch for the duration of the investigation

Scoring: 100-90 points - Discrete content concept selected and well defined by investigation
Plan has specific and thematic references to an existing curriculum
Level of openess is well-defined and substantiated
Complete Thinking Schedules or Tables of Variables are included
Daily sketch plan details active work on each day of the investigation

80-89 points - Discrete content concept selected and defined by investigation, but minor components are omitted
Plan has some references to an existing curriculum but without specificity or thematics
Level of openess is defined but not substantiated
Incomplete Thinking Schedules or Tables of Variables are

included
Daily sketch plan details active work on most days of the investigation

<79 points - Content concept selected, but minor components are omitted or are inappropriate to the investigation
Plan has limited or no references to an existing curriculum and lacks specificity or thematics
Level of openess is not well defined or substantiated
Thinking Schedules or Tables of Variables are substantially incomplete or omitted
Daily sketch plan details active work on most days of the investigation

THE NATIONAL SPACE GRANT AND FELLOWSHIP PROGRAM: NATIONAL MATHEMATICS, SCIENCE, AND TECHNOLOGY EDUCATION STANDARDS

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The National Space Grant College and Fellowship Program

A Nation at Risk in 1983 focused national attention on the American educational system. Other reports followed, describing the failures of the educational system and the implications for America's economic future. As the economies of the industrialized nations shift toward advanced technology manufacturing, and services, information and communications technologies, the jobs available will require increasingly higher levels of education. NASA Administrator Daniel Goldin at the 1996 Space Grant Conference agreed, saying there is a revolution taking place in technology; 50% of the U.S. jobs will be in the information processing arena which requires increase education in mathematics, science, and technology. In response to the many reports criticizing American education, former President George Bush and the Governors Council, chaired by then-Governor Bill Clinton, announced six national education goals. These goals are being implemented under President Clinton's administration and the U.S. Department of Education's *Goals 2000* program.

Of particular interest to NASA is *Goal 4*: "By the year 2000, U.S. students will be first in the world in science and mathematics achievement." The American space program is dependent on the educational system to produce quality scientists, mathematicians, and engineers to carry out NASA's strategic mission.

In response to the crisis in mathematics education, the National Council of Teachers of Mathematics (NCTM) released *Curriculum and Evaluation Standards* for school mathematics. These standards reflect a consensus of mathematicians and mathematics educators of how mathematics curriculum must be reformed. Emphasis is placed on active mathematics learning, based on students' natural curiosity. NCTM in 1991 released a companion standards on the teaching of mathematics.

Science educators followed the lead of NCTM and have developed national standards for science. The American Association for the Advancement of Science (AAAS) released in 1989 *Science for All Americans.* This report describes *Project 2061,* a plan to determine long-term science and mathematics needs of students. *Project 2061* has identified a small number of common themes, such as constancy and scale, on which future curricula would be based. AAAS released in 1995 *Project 2061* Benchmarks, which describe what every student should know in grades K-4, 5-8, and 9-12. The National Science Teachers Association (NSTA) supports *Science for All Americans* and developed a plan to reform secondary science education. *Scope, Sequence, and Coordination* eliminates the traditional layer cake curriculum and science is taught in a manner that identifies the connections between the science disciplines. The National Research Council (NRC) released in 1995 *The National Science Education Standards*. They present a framework for excellence and systemic reform in science education. The *Technology For All Americans Project* is currently developing standards for technology education. The technology standards should be released for public comment and review in 1997. Unlike many nations, the U.S. does not have a national curriculum. State adoption of national standards is voluntary. In an effort to promote the National Education Goals, the U.S. Department of Education has initiated *Goals 2000* to provide states with funding to develop state frameworks for improving education. Most states have developed state frameworks for education; however, not all have adopted national standards. Because of NASA's need for experts in science, mathematics, and technology, there is an interest at NASA to support the adoption and implementation of national standards in science, mathematics, and technology education.

The National Space Grant College and Fellowship (NSGC&FP) program is in a unique position to support standards. NSGC&FP program, modeled after Federal Land Grant and Sea Grant university programs, was mandated in 1988 with passage of the NASA Authorization Act. Like Land Grant, Space Grant has a presence in every state, Puerto Rico, and the District of Columbia, with over 580 affiliates including universities and colleges, business and industry, and government. The affiliate membership has a large stake in improved science, math, engineering, and technology education. This provides the rationale for their involvement in systemic reform. Table 1 summarizes the composition of the consortia.

Table 1

Space Grant Affiliates

Academic Institutions	410
Industrial Affiliates	68
State/Local government	31
Nonprofit organizations	41
Other	33
Total	586

Currently the 52 consortia administer programs in research, education and public service. Table 2 shows the breakdown of Space Grant Consortia expenditures.

Table 2

1995 Space Grant Expenditures

Category	%
Fellowships and Scholarships	13
Management	17
Public Service	4
Precollege (K-12)	20
Research Infrastructure	34
Higher Education	13
1995 NASA Space Grant Funds	$14.6 million

Approximately 20% of Space Grant activities are K-12 related. Space Grant programs serving both teachers and students, provide good examples of higher education working well with local school systems. Subsequently, the Space Grant consortia have been very successful in leveraging funds that promote NASA-related science education. During the period 1992-94, the consortia leveraged $16.5 million for over 1300 precollege projects. Many of these projects targeted persons from underrepresented groups and contain mentoring or role modeling components. After the release of science and mathematics standards, NASA's Education Division through the NSGC&FP was provided an opportunity to facilitate awareness, adoption, and implementation of national standards.

By participating in the Global Learning and Observations to Benefit the Environment (GLOBE) program, and NASA's Mission to Planet Earth (MTPE) strategic enterprise to train teachers to teach interdisciplinary science Space Grant affiliates are modeling programs that reflect the standards. The GLOBE program, an outgrowth of Vice President Al Gore's continuing interest in the environment, exemplifies the spirit and intent of the standards.

The GLOBE program, announced on Earth Day, April 1994, is an international science and education program that joins students, teachers and scientists to study the global environment and the Earth as a system. The GLOBE mission is to enhance the environmental awareness of individuals worldwide, increase scientific understanding of the Earth, and improve achievement in science and mathematics education. Students perform hands-on environmental science, make environmental measurements at or near their schools and send data electronically to a GLOBE data processing center. The student data are made available to scientists who analyze the data and provide information back to the students through visualizations. Since the GLOBE program was announced, over 2,500 US schools and 40 countries have registered. The GLOBE public sector partner is a U.S. Government interagency program involving the National Oceanic and Atmospheric Administration, NASA, National Science Foundation, Environmental Protection Agency, and the Departments of Education and State. In December 1994, the United Nations endorsed GLOBE and encouraged nations to participate. The international GLOBE partners include: Argentina, Australia, Austria, Belgium, Benin, Bolivia, Chad, China, Costa Rica, Croatia, Czech Republic, Ecuador, Egypt, El Salvador, Estonia, Fiji, Finland, Gambia, Germany, Greece, Ireland, Italy, Israel, Japan, Jordan, Kazakstan, Kyrgyzstan, Korea, Luxembourg, Marshall Islands, Mexico, Moldava, Morocco, Netherlands, Norway, Portugal, Romania, Russia, Senegal, Sweden, Trinidad and Tobago, Tunisia, Turkey, United Kingdom, United States, and Uruguay.

At the state consortium level, a review of currently funded K-12 projects sponsored by Space Grant has been completed. Individual projects are now being evaluated to determine if they meet the National Standards, particularly in the areas of teacher and preservice teacher enhancement. To further facilitate use of the standards, the evaluation of state consortia education projects has changed. In 1996, Space Grant affiliates will have to describe how their education programs meet the national standards. This will be accomplished through Space Grant's Internet reporting system.

NASA's Education Division is funding a new initiative, Project NOVA, to create change in higher education science, mathematics, and engineering courses. Space Grant institutions are participating in this program. This project promotes the development of interdisciplinary teams of university faculty to develop integrated interdisciplinary introductory courses for preservice teachers. At the center of this program is adherence to the national standards. As a result of the NSGC&FP consortia, science education reform is supported throughout the U.S.

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DEVELOPMENT OF AN INFORMAL LEARNING ASSAY

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Introduction

Research suggests that students' life experiences are important in the development of their science knowledge and social skills (Resnick, 1987). With children spending 85% of their time, sleep excluded, outside the classroom (Medrich et al., 1982), the types and frequencies of activities in which children are engaged during this time may have profound effects on their abilities in school and functioning in society. Working on hobbies, reading, performing domestic chores and participating in sports, coupled with the social interaction involving peers and adults, are a few of the myriad of activities that may contribute to students' learning through informal experiences.

The idea that learners use personal experiences to construct knowledge of the world around them is basic to the constructivist view of intellectual development. Experiences (physical, logical-mathematical), cognitive conflict and social interaction are important components of learners constructing such knowledge (Piaget, 1964; Rogoff, 1990; Vygotsky, 1978, 1986). These components are distinctive features of childrens' informal or out-of-school activities.

Lawson (1988) found that interaction with perceived authorities (e.g., adults, books, television) was the primary source of early acquisition of biological knowledge in elementary students. Further, this knowledge was acquired by gradual accretion primarily through informal experiences. Similar research demonstrating the modification of domain-specific knowledge through informal experiences is common in the literature (Bar et al., 1994; Brickhouse, 1994; Bryant & Marek, 1993; Carter & Jones, 1994; Lee et al., 1993; Lewis & Linn, 1994; Marek, Cowan & Cavallo, 1994; Odom & Barrow, 1995; Rice & Feher, 1987; Shepardson, Moje & Kennard-McClelland, 1994; Strommen, 1995; Sunal & Sunal, 1991; Westbrook & Marek, 1991, 1992). Unfortunately, few studies exist concerning the more critical question of how students' differing experiential backgrounds can be identified and measured.

Schibeci and Riley (1986) examined the influence of the informal learning environment of the home on science achievement in 673 seventh-graders. The researchers used responses from a four-item questionnaire as a measure of students' home environment. A sample item from the questionnaire included: Is there an encyclopedia in your home? Data from this assessment was used to conclude that the home environment had a substantial influence on science achievement.

Zuzovsky and Tamir (1989) examined the amount of variance in science achievement that was explained by variables of the home environment in a study of 2,599 elementary students. In this study, socio-economic status (SES) of the students was used as a measure of home variables. The SES of each student was measured by evaluating four variables: years of formal education of the mother, years of formal education of the father, number of siblings in the family, and number of books at home. The contribution of home variables to science achievement was found to increase when achievement was measured on topics not related to the school curriculum.

In a study that examined behaviors identified as important indicators of informal science learning, Tamir (1990) studied a total of 544 tenth-grade students in Israel and South Africa. The behaviors identified as important indicators of informal science learning included: after-school conversations of what was learned in school, watching television, listening to the radio, reading, and performing other science-related activities. Data were collected through mailed questionnaires to a number of schools. Each of the four behaviors were found to be positively correlated to each of the following: relationship of school science to everyday life, attitudes toward science, parental occupations, school environment, intentions for continuing science study, and career ambitions.

Evans, Baumert and Geiser (1995) developed an instrument to assess the out-of-school experiences of fourth-graders. A total of 517 students were included in the study, 195 from the U.S. and 322 from Germany. The instrument consisted of several specific questions for each of five domains: mechanical/technical, household, nature, creative, and musical. Examples of the types of questions used in the study included: Do you use an electric drill or saw? and Do you use sewing scissors or measuring tape? This information, along with data from self-efficacy, motivation and science achievement measures, was used to show that if school assessment measures included the household experiences of students, then those with high involvement in household activities would have higher control beliefs and higher science achievement.

The methods used to assess informal learning environments vary widely. Little progress has been made toward completing a comprehensive and reliable instrument to quantify students' informal learning environments. Yet, experiential learning and its influence on cognitive and

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affective aspects of students of all ages is frequently cited in the science education literature.

Science education literature is replete with statements concerning students' informal learning experiences and their possible influence on experimental results. A review of one year of Journal of Research in Science Teaching (1995) showed that nearly every issue contained at least one article with statements to this effect (Baker & Leary, 1995; Greenfield, 1995; Gurney, 1995; Korthagen & Lagerwerf, 1995; Kyle, 1995; Lee, Fradd & Sutman, 1995; Lumpe & Staver, 1995; Roychoudhury, Tippins & Nichols, 1995; Strommen, 1995; Watson, Prieto & Dillon, 1995; Watters & English, 1995). Before statements such as these can be substantiated, an instrument is required that reliably measures students' informal learning experiences.

Problem Statement

The purpose of this study was to develop an instrument to reliably quantify middle school and high school students' informal learning experiences. To be a useful tool to teachers and researchers, the instrument should be easy to administer and score, be useful with ethnically and culturally diverse student populations, and have the "flexibility" to be used across the disciplines.

Defining Informal Learning

Most science curricula include only that knowledge to be acquired in the classroom within a systematic educational setting (e.g., primary and secondary schools, technical schools, colleges, universities). Through these curricula, educating students takes place in organized, systematic ways. The learner and teacher interact with the prescribed intent of promoting learning. A set agenda is implemented and little, if any, importance is ascribed to childrens' experiences outside the classroom (Osborne & Wittrock, 1983). In this setting attendance is compulsory, subject matter is structured by a teacher, motivation is primarily extrinsic and some type of assessment is expected (Tamir, 1990). The learning that takes place is termed "formal" due to the highly structured nature of the environment in which it occurs.

Learning that takes place in settings outside of the classroom is termed "informal" (Maarschalk, 1988; Tamir, 1990). Informal learning environments are less structured than the formal classroom setting and management of the learning is shifted from the teachers to the students (Tamir, 1990). Informal learning may occur in institutions (e.g., museum, zoo); organizations (e.g., Boy/Girl Scouts, Junior Achievement); or everyday situations (e.g., watching television, taking piano lessons, working on hobbies, shopping for clothes). For the purposes of this study, the informal learning environment is the sum of activities that comprise the time students are not in the formal classroom in the presence of a teacher.

The Context of This Study

Most science education research examines some aspect of the formal classroom environment. The lack of educational research on informal learning is substantiated by Lucas (1991) who completed a review of informal science learning articles published from 1983 to 1991. He found 163 entries with nearly every article dedicated strictly to museum research. Only a few studies were actually reports on the process of learning science through informal activities other than museum visits. Museum visitation research is one area of informal learning that has shown a tremendous increase in the science education literature (Dierking & Falk, 1994; Ramey-Gassert, Walberg & Walberg, 1994). This is presumably due to the large increase in numbers of science museums as well as ease of observing and testing museum patrons. However, the majority of childrens' nonschool time is spent on informal activities unrelated to museum activities. This time is unaccounted for in science education research due to the difficulty of evaluating such heterogeneous subjects, learning environments, activities, and everyday learning situations. Aside from museum studies, research on informal learning is not as researcher friendly as the data gathering for research in the traditional classroom arena. However, considering the potential impact these out-of-school activities may have on student learning in school, a greater understanding of informal learning may have profound implications for the educational community.

This paper describes the instrument development portion of a larger study which was designed to examine relationships among informal science learning experiences, teaching procedures in the formal science classroom environment, and scientific reasoning ability. This investigation has resulted in a reliable and valid instrument, the Informal Learning Assay (ILA), for assessing students' informal learning activities.

Developing the ILA

Content Validity

Initial construction of the ILA began by designing questions to assess students' involvement in a wide variety of informal activities (e.g., hobbies, sports, clubs, travel, television). The content-related validity of the ILA was established by a panel of experts. The panel included two science education researchers with a total of 22 years experience in educational research, two middle school science teachers with a total of approximately 40 years of science teaching experience, and an educational psychologist experienced in assessment techniques. Members of the panel suggested, 1) the addition of questions assessing students' involvement in church youth groups and volunteer work, and 2) identifying the number of siblings in a family. Following these changes, the panel agreed that the ILA was appropriately formatted for middle school and high school students and comprehensively assessed their informal learning experiences. The ILA was field tested to further assess validity through student interviews and to assess reliability.

Field Testing

The ILA was administered in September/October of the academic school year to 2,128 students enrolled in sixth-, seventh-, eighth-, ninth-, and tenth-grade science classes. Students were from nine middle schools and two high schools in a Midwestern state. Schools were located in rural, suburban and urban settings and ranged in size from very small, with approximately 50 students per grade level, to very large, with approximately 325 students per grade level. Students from eighteen female teachers and thirteen male teachers participated in the study. Teaching experience among these thirty-one teachers ranged from 2 to 26 years and averaged 10.6 years.

The student sample consisted of the following percentages by grade: 15.9%, sixth-grade; 19.1%, seventh-grade; 28.3%, eighth-grade; 11.7%, ninth-grade; and 25.0%, tenth-grade. The sample included African Americans (6.5%), Asian Americans (3.8%), Whites (79.1%), Hispanics (2.5%), Native Americans (5.8%), and students classifying themselves as ethnically mixed (2.2%). Female students made up 51.5% of the sample and males made up 48.5%. Students' grades in science for the previous year were 42.5% "A," 35.8% "B," 15.7% "C," 4.6% "D," and 1.4% "F."

The final version of the ILA consisted of 41 questions. Nineteen items were multiple choice and required students to indicate the extent of their involvement in various informal activities. Nineteen items required yes/no responses. Three items required students to fill-in-the-blanks. Directions at the beginning of the ILA instructed students to circle or write the appropriate response for each item in the space provided on the instrument.

Questions on the ILA were separated into seven categories for the purpose of describing the instrument. These categories included: social activities with family and/or friends; activities done alone; school-related activities; lessons, classes or group activities not school-related; work and domestic chores; travel; and general.

Fifteen ILA items assessed students' involvement in *social activities with family and/or friends*. See Table 1, items 8, 12, 14 and 35, for examples. Ten multiple choice questions investigated patronage of restaurants, public libraries, movie theaters, and community parks; visiting attractions such as sporting events, natural areas, museums, and amusement parks; frequency of bicycle riding, skateboarding or roller blading; and with whom they go shopping for clothes and groceries. Four questions required yes/no responses. These items investigated receiving help with homework, running family errands, participating in sports, and the presence of siblings. One fill-in question required students to list the four most common things they do with friends.

Six questions on the ILA assessed students' involvement in *activities done alone*. See Table 1, items 2 and 4, for examples. Three questions were multiple choice and investigated the time students spend reading books and magazines, watching television and listening to the radio. Two fill-in questions required students to list favorite television programs and the four most common things they do alone. One yes/no question assessed involvement with hobbies.

One multiple choice question (Table 1, item 17) assessed students' involvement in *school-related activities*. Students indicated past or present involvement in school-related activities by circling the appropriate choices from a list of eight provided. Space was provided for students to record activities not mentioned in the list.

Four questions on the ILA assessed students' involvement in *lessons, classes, or group* *activities not school-related.* See Table 1, items 18 and 22, for examples. Three yes/no response items assessed involvement in Scouting, Future Farmers of America or 4-H, and church youth groups. One question was similar to the school-related activities item except that twelve, nonschool-related activities were listed.

Three questions assessed students' involvement with *work and domestic chores.* See Table 1, item 27, for an example. Two yes/no response items investigated student involvement with paying jobs outside the home and volunteer work. One question required students to circle all domestic chores, from a list of fifteen provided, they regularly performed. Space was provided for students to record chores not mentioned in the list.

Six questions assessed students' *travel* experiences. See Table 1, items 39 and 41, for examples. All items required yes/no responses and surveyed their history of domestic and international travel/living.

Six items on the ILA were *general* questions not related to each other or to previously mentioned groups of questions. See Table 1, items 20 and 28, for examples. Three yes/no response items investigated receiving an allowance, and possessing a personal home computer and a library card. Three multiple choice questions assessed the time students spend using a computer and shopping for clothes and groceries.

Table 1
Sample Items on the ILA

2. How many hours a day do you watch TV? a. more than 6 hours b. between 3 to 6 hours
c. between 1 to 3 hours d. between 0 to 1 hour

4. Do you have any hobbies, like collecting or making things? a. yes b. no
* If yes, what are your hobbies?
a. ____________________ b.____________________

8. In the afternoon and on weekends, do you usually spend time with brothers and sisters, friends, or by yourself?
a. brothers and sisters b. friends c. by myself

12. Where do you and your friends usually spend time together?
a. in your own house or yard b. in friends' houses or yards c. in a park
d. in a shopping mall Other________________________

14. How often do you usually go to the movie theater?
a. once a week or more b. a few times a month c. a few times a year or l

table 1. cont.

17. Are you involved in any school related activities? a. yes b. no
* If yes, circle all of the school activities in which you have been actively involved?
a. Student Council or Government
b. School Band or Orchestra
c. School Drill Team or Cheerleaders
d. School Newspaper
e. Student Helpers in School Office or for a Teacher
f. School Sports Teams That Play Other Schools
g. Science/Engineering Fair
h. Academic Contests
i. School Sponsored Clubs (such as Photography or Drama Club)____________________
j. Any School Activities Not Listed ____

18. During the past year, have you attended any lessons or classes that are not school related?
a. yes b. no * If yes, what type of lessons or classes have you attended?

a. Music Lessons
b. Art Lessons
(such as drawing or painting)
c. Cooking or Sewing
d. Tennis Lessons
e. Dance Lessons
f. Crafts
(such as pottery or jewelry making)
g. Religious Instruction
h. Martial Arts (such as Judo or Karate)
i. Dramatics or Acting
j. Nature Study or Science
k. Swimming Lessons
l. Sports Clinics
m. Any Activities Not Listed ____

20. Do you have a personal computer at home? a. yes b. no

22. Have you ever belonged to the Girl/Boy Scouts or Campfire Boys and Girls? a. yes b. no

27. Have you ever done volunteer work for any group (such as Red Cross, United Way or Nature Conservancy)? a. yes b. no
* If yes, with what group(s) did you volunteer?______________________________
Describe what you did as a volunteer.___________________________________

28. Do you receive an allowance? a. yes b. no
* If yes, on what do you usually spend the money?___________________________

31. Do you usually go clothes shopping alone or with adults (such as a parent or guardian)?
a. alone b. with an adult

35. Does an adult (such as a parent or guardian) regularly help you with school work?
a. yes b. no

39. Have you ever traveled outside of the United States? a. yes b. no
* If yes, list where you traveled and how long you stayed there.____________________

41. Have you ever traveled outside of the state in which you are currently living? a. yes b. no
* If yes, list where you traveled and how long you stayed there.____________________

Throughout the field testing the ILA was administered by the researcher or by the classroom teacher in the presence of the researcher. All teachers agreed that the information provided by the ILA would be useful to them, generally stating the more they know about their students the more effectively they can teach. Specifically, most teachers stated that the usefulness of understanding students' experiential background included, 1) knowing what type of examples and demonstrations to provide in class so students would better understand the current science topic, and 2) being able to equitably separate students into cooperative groups. For some teachers this meant grouping students with similar experiential backgrounds; and for other teachers it meant grouping students with different experiential backgrounds so that they could learn from each other.

Scoring

Scores on the ILA could range from a low of zero to a high of approximately fifty. The upper limit is variable since some items on the ILA allow students to receive additional points by indicating their involvement in activities not listed. Responses to most items on the ILA were scored so that either a "one" or a "zero" was added to a student's total score. On all yes/no items a "yes" response received one point and a "no" response received a zero.

Multiple choice questions consisted of four types: 1) amount of time spent on an activity, 2) with whom time is spent, 3) where time is spent, and 4) identifying activities which may occupy free time. Responses indicating a minimal amount of time spent on an activity were scored a zero. Responses indicating more frequent time spent on an activity received one point. For example (Table 1, item 2), a response of "between 0 to 1 hour" received a zero while a response of "between 1 to 3 hours," "between 3 to 6 hours," or "more than 6 hours," received one point. In Table 1, item 14, a response of "a few times a year or less" received a zero while a response of "a few times a month" or "once a week or more" received one point. For the purpose of this study, discrimination was needed only for dichotomous responses. For example, between 0 to 1 hour is essentially not sufficient to contribute to learning whereas over one hour would provide adequate engagement in learning. However, the range of choices were included to provide avenues for future research.

Multiple choice questions assessing with whom time is spent were of two types. One type of question included responses indicating a lack of social interaction (Table 1, item 8). A response of "by myself" received a zero. Responses indicating time spent with "friends" or "brothers and sisters" received one point. Conversely, scoring of the second type of question (Table 1, item 31) reflected the high degree of decision-making involved in shopping alone. A response of "with adult" received a zero while a response of "alone" received one point since the evaluation of various elements associated with a purchase rested solely with the student.

One multiple choice question assessed where students and their friends spend time together (Table 1, item 12). A response of "in your own house or yard" received a zero while a response of "in friends' houses or yards," "in a park," or "in a shopping mall" received one point since activities at these locations might encourage social interaction to a greater degree than in their own house or yard.

Two multiple choice questions identified activities which could occupy students' time. See Table 1, item 17, for an example. Participation in school-related activities (e.g., band, school newspaper, Student Council) and lessons or classes not school-related (e.g., martial arts, acting, sports clinics) likely encourage social interaction since these activities are led by adults and involve cooperative groups. One point was added to a student's ILA score for each item circled or written in the space provided at the bottom of these two questions.

Conversely, activities such as domestic chores (e.g., doing laundry, feeding pets, washing dishes) and visiting attractions (e.g., sporting events, amusement parks, museums) are not as likely to expose students to cognitive challenges or extensive social interaction. The multiple choice question assessing involvement in domestic chores required at least four chores to be circled to receive one point. Responses with fewer than four chores circled received a zero. The multiple choice question assessing involvement in visiting attractions required at least three attractions to be circled to receive a point. Responses with fewer than three attractions circled received a zero. Multiple responses were required for a point to be awarded on these questions since the activities mentioned are short-term events and therefore cognitive challenges and social interactions are limited. However, numerous exposures to these informal events likely introduces students to some positive cognitive and social interactions. The number of activities needed for awarding point values to these two items was determined so that equivalent informal learning opportunities were represented.

As a result of the scoring procedure, a high score on the ILA indicated an enriched informal learning environment with frequent exposure to experiences that provide cognitive challenges and social interactions. Alternatively, a low score on the ILA indicated an impoverished informal learning environment with infrequent exposure to experiences that provide cognitive challenges and social interactions.

Students required between 15 to 35 minutes to complete the ILA. Sixth-graders required the most amount of time to complete the instrument while tenth-graders required the least amount of time. Scoring of each ILA was completed by the researcher and required about one minute per data sheet. Scores for each question were keyed into a computer and were analyzed using the SYSTAT/Mac (Wilkinson, Hill & Vang, 1992) statistical package.

Validity and Reliability

Scores on the ILA for the 2,128 students ranged from 0 to 46. The distribution of scores approximated a normal curve with a mean of 22.57 and a standard deviation of 5.07. Table 2 shows the corresponding values for each grade and totals. The internal-consistency of the instrument was estimated using the split-half reliability estimate and Spearman-Brown formula (r=.82).

Table 2
Summary Statistics for the ILA

Grade	*N*	*M*	Range	*SD*
6	338	22.51	9-39	5.02
7	407	21.75	0-37	4.93
8	602	23.24	6-46	5.16
9	250	23.00	11-40	5.25
10	531	22.29	6-37	4.90
Total	2128	22.57	0-46	5.07

Two students from each of five different categories of ethnic origin (i.e., African American, Asian American, White, Hispanic, Native American) were interviewed following completion of their ILA. All ten students had the same understanding of each question on the instrument. Results of these interviews concurred with the findings of the panel of experts. The ILA was determined to be, 1) useful with ethnically and culturally diverse student populations, and 2) an inclusive assessment of students' informal learning experiences.

Discussion and Implications

The informal learning experiences of children are being recognized in the education research literature. However, a reliable instrument that extensively assesses students' informal learning has yet to be introduced. This study has produced such an instrument, the ILA.

Mean ILA scores for students in each grade were within a range of 21.8 to 23.2 indicating student informal activity remained similar from middle school through tenth-grade. This was the initial use of the ILA, therefore, it is difficult to assess how these average scores would compare to other student samples. However, the highest score from this sample was 46, indicating students' potential for increased contact with informal learning opportunities is great. Future studies using the ILA will explore possible differences in the informal learning environments of diverse student populations.

While the ILA may be useful to classroom teachers, it was constructed primarily as a flexible tool for research in science education. This instrument could serve as a vehicle to initiate research in science education topics where it is difficult to obtain reliable quantitative data of the nature generated by the ILA. The ILA provides a useful means of answering questions such as: What are the relationships among gender, age and types of informal learning experiences? What are the experiential differences between males and females among urban, suburban, and rural settings? How does the structure and use of science knowledge differ among students from contrasting informal learning environments? How are attitudes toward science related to students' informal learning experiences? How do socio-cultural differences among students affect informal learning experiences? What is the relationship between cognitive development and informal learning environment? These questions provide examples of the applicability of the ILA to various problem statements or hypotheses in science education research.

Informal learning experiences have been identified as influential in a wide variety of science education research. The great amount of time students are engaged in experiences outside the formal classroom presents a tremendous learning potential. However, students' informal learning environments are under-studied. The ILA could provide science education researchers a means of furthering our understandings of knowledge formation, cognitive development and the affective influences of the informal activities of children.

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COLLABORATION IN THE CLASSROOM: A FRAMEWORK FOR RESEARCH AND PRACTICE

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Introduction

The current reforms present the dual challenge of designing inquiry-driven instruction and creating communities of learners in science classrooms (AAAS, 1993; NRC, 1996). An important goal of innovative instruction is to foster in-depth understandings of science content and processes; a goal shared by most practicing teachers. Learning communities offer potential academic and social opportunities for students to debate ideas, distribute knowledge, and gain social responsibility (Brown, Collins, & Duguid, 1989; Lave & Wenger, 1991; Rogoff, 1990). The idea of a learning community has gained attention as a desirable environment that could engage students in solving problems in collaboration with peers. Yet the reform documents fail to provide clear descriptions of how a teacher can create a community of learners.

The development of a learning environment supporting inquiry is one of the charges made to science teachers of all levels. Teaching Standard E of the National Science Education Standards states that "Teachers of science develop communities of science learners that reflect the intellectual rigor of scientific inquiry and the attitudes and social values conducive to science learning" (NRC, 1996). Although a few examples of actual teaching scenarios are included in this document, more detailed explanations of how a classroom teacher might design this kind of environment appears critical to successful implementation.

Research has shown that this kind of instruction is rare in today's classrooms (Gallagher, 1989), difficult to carry out, and requires teachers and students to take on new roles and responsibilities (Rogoff, 1994). Facilitating a community of learners involves the teacher transforming his or her role from being the main authority of knowledge to that of empowering students. This transformation of roles can be problematic for teachers and for students. The sharing of the teaching and learning is contradictory to traditional teacher and student roles in K-

12 classrooms. Key to creating a community of learners is the clarification and articulation of the roles of teacher and students.

There are some examples in the literature of learning communities in mathematics classrooms (e.g. Ball, 1990; Lampert, 1990; Wilcox et al., 1991; Wood et al., 1991) in which students and teachers collaborate to develop in-depth understandings of mathematical concepts. However, there appear few examples of these kinds of collaborative environments in science classrooms.

Goals of the Research

In studying my own teaching I explored the interactions of my 8th grade physical science students and me to determine important aspects of classroom work that correspond to a community of learners. The goals of this study are first to identify the critical components of a science classroom community of learners, and second to develop a working model for practicing teachers and researchers that engages students and teacher in real-world, collaborative science learning.

The Researcher

As a teacher with 18 years of public school teaching experience, I am concerned with translating research findings from scholarly literature into usable guidelines for the classroom teacher. Educational jargon and words written inside the ivory tower often remain inaccessible to classroom teachers. Research findings often fail to relate to day to day lessons, remaining obscure to practitioners. This report focuses on the analytical framework for a study that involved designing an inquiry-based course of instruction for my middle school students, teaching this course of instruction, and analyzing the collaborative student-student and student-teacher interactions (Crawford, 1996). By looking carefully at the analytical framework, I reflected on what happened in my science classroom, and in other classrooms I have researched. Having formal education in biology, chemistry and microbiology, and professional experience in scientific research and development, I am admittedly passionate about engaging students in long term investigations (Dewey, 1938). My beliefs of teaching and learning stem from social-constructivist perspectives (Lave & Wenger, 1991; Rogoff, 1990,1994; Vygotsky, 1978). This view of learning envisions knowledge construction as a process facilitated by discourse and social interactions (Brown et al, 1989; Newman et al., 1989). In this social constructivist view of learning, scientific knowledge is socially constructed, validated, and communicated.

Instructional Design

Only a brief description of the instructional design will be included in this report. (See Crawford, 1996). The instruction was designed to promote in-depth understandings of science processes and content through solving meaningful problems (Blumenfeld et al., 1991; Brown et al., 1989). Using this project-based approach, I designed a course of instruction that focused students on investigating hazardous substances in their lives. This project-based instruction featured a driving question, *Are There Poisons In Our Lives?*, that linked concepts of matter and changes in matter to the lives of the student and teacher. (See Krajcik et al., 1994, for features of project-based science instruction and characteristics of the driving question.) The design of this inquiry-centered instruction was based on the premise that students learn through projects (e.g. Dewey, 1938; Krajcik et al., 1994; Tinker, 1991). Although originally planned for eight weeks, the poisons project extended over a period of twelve weeks.

Method

Videotapes of lessons captured classroom interactions during the inquiry-based course of instruction. My physical science class consisted of 26 eighth grade students of diverse ethnic and economic backgrounds that I taught in the 1993-1994 academic year. The description of the particular class, school, community, and focus group of students appears in another report (Crawford, 1996). In order to determine which elements of a community of learners emerged in this classroom, a framework developed from the literature was used to focus the analysis. This framework for analyzing the interactions that occurred in my classroom emerged from three areas: constructivist views of learning; authentic instruction; and collaborative learning. A search for studies involving students engaged in a combination of inquiry and collaboration revealed six components of a community of learners: 1) instruction is situated in *authentic tasks*; 2) students develop *interdependency in small group work;* 3) students and teacher debate ideas and *negotiate understanding*; 4) students and teacher *publicly share ideas* with members of the classroom community; 5) students *collaborate with experts* outside the classroom; and 6) *responsibility for learning and teaching is shared.* (See Table 1.) Situating instruction in *authentic tasks* involves creating environments similar to those of practitioners (Resnick, 1987). In the case of the science classroom, authentic instruction engages students in pursuing answers to significant questions similar to activities of professional scientists (Brown et al., 1989). Solving problems and doing "real" science in the classroom stems from Dewey (1938) who believed that the school community is a place where a child gains authentic experiences by doing projects versus solving isolated problems. The importance of having group members acquire *interdependency* is addressed by Cohen (1986). Although group members may struggle at times, teachers should delegate authority to group members to communicate and depend on each other. Group learning is often equated with cooperative learning (Johnson & Johnson, 1991; Slavin, 1981) involving rules used by teachers for distributing group tasks. In establishing a community of learners in a science classroom all participants in the classroom collaborate in a social context, *negotiating meanings* and distributing expertise while solving authentic problems. Studies of classrooms in which students engage in collaborative interactions depict teachers as co-collaborators in developing in-depth understandings of important concepts (Linn & Burbules, 1993; Wood, Cobb, & Yackel, 1992). Smith (1991) describes a model of a learning community where students develop scientific understandings collectively. In this learning environment students *make public* their understandings in order to explore their ideas and modify these understandings towards a more scientific point of view. Opportunities to *collaborate with experts* may come from personal connections with people in the local community or from

Table 1.
Components of a Community of Learners in a Science Classroom

Component	Description	Literature Base
Authentic Tasks	Instruction is situated in tasks that are based on real-world problems	Brown et al., 1989; Dewey, J., 1938; Duschl & Gitomer, 1993; Lave, 1988; Resnick, 1987; Roth, 1994
Interdependency in Small Group Work	Group members function by relying on each other to complete a task	Bruffee, 1993; Cohen, 1986; Collins et al., 1989; Slavin, 1981; Wilcox et al., 1991
Negotiation of Understanding	Students and teacher debate ideas and negotiate understanding of substantive science content	Lampert, 1990; Linn & Burbules, 1993; Vygotsky, 1978; Webb, 1989; Wood, Cobb, & Yackel, 1992
Public Sharing	Students and teacher publicly share ideas with members of the classroom community	Duschl & Gitomer, 1993; Lampert, 1990; Smith, 1991
Collaboration with Experts	Students collaborate with experts outside the classroom community	Roup et al., (Eds.), 1993; Warren, Rosebery, & Conant, 1989
Shared Responsibility	Responsibility for learning and teaching is shared	Brown & Campione, 1990; Newman et al., 1989; Rogoff, 1994; Schwab, 1975; Wilcox et al., 1991

teachers extending the walls of their classrooms using telecommunications (Roup, Gal, Drayton, & Pfister, Eds., 1993). *Sharing responsibility for learning and teaching* involves a transformation of participation in which the roles of the members in the classroom change with the change in sociocultural activities (Newman et al., 1989; Rogoff, 1994).

These six components do not necessarily reflect the original intent of the authors of each of the studies or position papers. Instead these six components emerged from careful consideration of numerous articles on collaboration in classrooms written by cognitive psychologists and educational researchers from a variety of disciplines. This framework served to organize the data in the study of my teaching and to identify patterns that developed during instruction (Yin, 1989). For each of the six components, a range of characteristics from traditional to intermediate to constructivist determined characteristics in the classroom. The continua used to analyze the nature of the interactions is shown in Tables 2-7.

The analysis of the videotaped lessons consisted of a three part process involving data reduction, data display, and conclusion drawing and verification (Miles & Huberman, 1994). Narrative summaries of the video-taped lessons were first written. These summaries were then critically analyzed for components of a community of learners using the framework. Following the writing of the summaries and identification of important sections relating to the components, attention was drawn to finding patterns that emerged across the lessons. This review of the videotapes produced documents that contained lesson descriptions, segment summaries, commentary, and hypotheses. Two other researchers collaborated on the process of data reduction and analysis used in interpreting the videotapes that contributed to final emergence of themes and tentative conclusions.

Table 2.
Characteristics of Authentic Tasks
What is the nature of the task?

Environment	Characterization	Example
Traditional	Instruction is situated in topic areas and aligned with textbook chapters; Students learn by performing prescribed exercises	Students complete a worksheet by giving definitions for Newton's Three Laws as worded in the textbook
Intermediate	Instruction may be relevant to students' lives; however tasks are determined mainly by the teacher	Students bring skateboards to school; students carry out investigations outlined by the teacher that relate to Newton's Second Law and how it affects riding on a skateboard
Constructivist	Instruction is anchored in students' lives and situated in real-world contexts; Students take ownership of the problem area, and formulate their own questions	Students ask and refine their own questions relating to force and motion; students carry out their own investigations relating to Newton's Second Law, such as how it pertains to riding on a skateboard, riding a bicycle, or riding on a roller coaster

Table. 3.
Characteristics of Interdependency in Group Work
What is the nature of the small group work?

Environment	Characterization	Example
Traditional	Students are guided maximally by directions given by the teacher for the small group work; instruction is mainly procedural	Students do a laboratory activity using pH paper to test three solutions following directions given by the teacher: Teacher goes over all directions carefully: " Label one cup 'Cup A', another cup, 'Cup B'.. "
Intermediate	Students work in groups, but they ask the teacher frequently for direction during their group discussion	Students work in groups discussing the design of an investigation of acids and bases in their homes. The teacher constantly circulates through the room, stopping often to tell the students how to structure the investigation
Constructivist	Students help determine the direction of their investigation; students look to group members instead of mainly to the teacher for ideas	After brainstorming in their group, students choose to investigate acids and bases in their homes. They independently decide among themselves which household substances to test, how to design the investigation, and how to carry it out

Table 4.
Characteristics of Negotiation of Understanding
What is the nature of the dialogue in the groups?

Environment	Characterization	Example
Traditional	Students do not ask unsolicited questions; teacher tells students his/her interpretations; dialog related to procedures of the task/lab activity; students appear passive during the lesson	Students discuss the correct procedure for using pH paper and how to label the cups in testing the acidity of some solutions; students concerned mainly with completing the task
Intermediate	Students initiate discussion of ideas of science concepts or processes	Students brainstorm ideas of vitamins that may be hazardous to humans, individually giving ideas, but do not sustain a discussion
Constructivist	Students actively participate during the lesson; students discuss ideas with others; teacher and students generate interpretations collaboratively; student discourse is related to debating ideas within small groups versus procedural or off-task talk	Students discuss how to best set up an investigation to determine the effect of different vitamins on plant growth; students debate how many plants to use, what vitamins to use, how to measure the growth, and how to make sense of the data

Table 5.
Characteristics of Public Sharing
What is the nature of the reporting of ideas?

Environment	Characterization	Example
Traditional	Students receive science knowledge as a well defined body of information from the teacher who is the main transmitter of information in whole class format	Students listen to teacher lecturing on definitions of atoms, molecules, and compounds; students privately discuss understandings
Intermediate	Students report to others in the class information found in textbooks and encyclopedic source	Students report to the class information gained mainly from the textbook about the chemical composition of asbestos, and its health effects on humans
Constructivist	Students share their own ideas publicly with other members of the class for feedback and revision	Students publicly share ideas of setting up an investigation of the effect of asbestos on plant growth; other students in the class question the experimental design, and suggest a better, and safer means of setting up the investigation

Table 6.
Characteristics of Collaboration With Experts
What is the nature of collaborating with experts?

Environment	Characterization	Example
Traditional	Students look to the teacher and textbook or encyclopedia as the main sources of information in the classroom	Students look up smoking and cigarettes in the library using the World Book, and then write up a report
Intermediate	Students seek help and gain information from experts outside the classroom from personal contacts or on-line networking	A group of students post an e-mail message on an electronic bulletin board asking for the latest information on carcinogens in tobacco. A scientist sends some recent information over the network
Constructivist	Students exchange ideas with experts outside the classroom through personal contacts or on-line networking	Students exchange ideas with a scientist on an electronic bulletin board about the latest information on carcinogens in tobacco; students share their own findings with the scientist, and exchange ideas

Table. 7.
Characteristics of Shared Responsibility in Learning and Teaching
What is the nature of the instructional roles of the students and teacher?

Environment	Characterization	Example
Traditional	Teacher uses directed teaching such as lecture to present scientific facts and to give information; teacher disseminates knowledge; students watch a demonstration	Teacher lectures on chlorine and the characteristics of the element in the periodic table; students see a video on chemical properties of chlorine
Intermediate	Teacher takes on the role of expert and guide leading students through a predetermined path to understanding defined science concepts and processes	Teacher plans a traditional verification laboratory to determine the concentration of chlorine in several water samples; the teacher predetermines the correct values
Constructivist	Teacher facilitates the students in gaining responsibility for their own learning; Teacher and students generate interpretations by working together; Students teach other students/and the teacher	Teacher enables students to collect data on concentrations of chlorine in the school drinking water and compare this to chlorine levels which are hazardous; students share their finding with the class and teacher

Results

The intent of this report is to suggest critical components of a science classroom community of learners. Equally important is the elaboration of these components for use by classroom teachers and researchers. The results of systematically analyzing the interactions of my students using the components of a community of learners continua revealed eight themes. These themes are reported in a separate paper (Crawford, Krajcik, & Marx, in review), and they relate to increased student interactions when tasks were student-initiated, connected to real-world questions, and relevant to students' experiences.

The results of the study revealed that students did not operate smoothly in the beginning weeks of the instruction. The students focused on carrying out procedures detailed in lab activities, but failed to engage in thoughtful conversations about the meanings of the science concepts and processes. After introduction of the driving question, *Are There Poisons in our Lives?* students became increasingly engaged in finding answers to their own questions relating to this overarching one. Clarification of my expectations of the students also appeared to increase the positive interactions and the productivity of the students. One key component that appeared particularly influential in increasing collaboration was the connection of students to experts outside the classroom. The second key component involved structuring the nature of the tasks; those tasks that related to real-world questions engaged the students in wrestling with important concepts. Vignettes from video-taped lesson segments are included to illustrate the components of a community of learners framework.

Overview of the Instruction

During the first two weeks of instruction, several hands-on activities and video laser-disc programs provided opportunities to discuss basic properties of matter and changes in matter. For example, students investigated the properties of a mixture of cornstarch and water, and debated the nature of the strange acting substance: was it a liquid or solid? Format for instruction varied from large group discussions to small group activities. The small collaborative groups of three to four students were purposely constructed to ensure heterogeneity of academic and social characteristics. Students worked in these groups throughout the twelve week course of instruction. After two weeks, an unexpected event coincided with the introduction of the overall driving question of the instruction: a chemical tanker overturned on the highway near the school causing immediate concern. Students initiated thoughtful discussions centering on the possible hazards of the spill and questioned policies of the local community.

Following this event, students brainstormed possible chemicals to investigate. Working in their teams, students selected a potential poison, and designed an experiment to explore the potential hazard of this chemical on humans. At this point, several of the teams of students struggled in designing their investigation and in simply working together as a team. Plenary sessions during which teams reported to the class their preliminary ideas for an investigation resulted in helpful feedback from peers and the teacher. Key to focusing the students and moving them towards setting up and completing their investigations was a teacher handout carefully outlining the descriptions and due dates of intermediary products in the study. Connection with experts using telecommunications and local people in the community heightened the students' productivity and interest in their study. During the final weeks of the instruction, each of the seven teams of students sustained increased levels of productivity as they focused on their conclusions, and worked on group presentations of their findings. Interviews of students verified the change toward a more collaborative environment as the students worked on investigations of their own design.

Situating Instruction in Authentic Tasks

In a science classroom authentic tasks simulate the kinds of activities in which scientists would engage. When tasks relate to real-world contexts, students develop understanding of science concepts by restructuring their current knowledge. During the second week of the instruction I brought in several containers from my home containing common household substances including cleaning agents, foods such as vinegar, drinking water, green colored water, and air. In this lesson I held up the various bottles, and asked the students to classify them as chemical or non-chemical. I asked the class in general, What is a chemical?

Sally: We don't know.
I: What is a chemical? Who knows?
Nathan: A liquid.
Tammy: Anything really.
Sarah: Something that you can mix to make something new.
Bobby: I don't know. Like a substance that can be changed by other substances.

As I held up each substance, I asked if it were a chemical. Students indicated mixed responses by raising their hands. When I held up the flask containing the green colored water, one boy initiated a response, and said it reminded him of toilet bowl cleaner. He then wondered about the purpose of the green color. Other than the question about the green color in the toilet bowl cleaner, the task elicited limited student interactions with me or other students in the class. As I held up the containers, the students appeared interested in looking at the various stuff. Even though students were unsure if the substance were chemical or not, they initiated few questions about the nature of the substances. The task involved looking at substances common to the everyday life of a middle school student. Yet, the task was largely teacher-directed and tied to the scientific definition of matter. The nature of the task was coded as intermediate between traditional and constructivist using the continuum below:

What is the nature of the task?

Environment	Characterization	Example
Intermediate	Instruction may be relevant to students' lives; however tasks are determined mainly by the teacher	Students bring skateboards to school; students carry out investigations outlined by the teacher that relate to Newton's Second Law and how it affects riding on a skateboard

Interdependency in Small Group Work

In a community of learners students working interdependently would begin looking towards members of the group for direction instead of solely to the teacher. Students working in interdependent groups depend on each other to achieve cognitive goals, and become self-directed. Eight weeks after the beginning of the instruction, the team studying vitamins finalized the design of their team investigation. One of the girls in the four member team had brought in a large bag of vitamins that her dad took each day. The members of the team exchanged ideas about how to set up an experiment, and after many days settled on applying various amounts of the crushed vitamins to different plants. One of the girls brought in over 30 vegetable plants of four varieties. Eventually the team members asked to use a section of the school greenhouse that they corded off with masking tape marked with large red letters. The two girls set up a schedule for the team members to take growth measurements during lunch time and after school, and designed the log for recording the data. One of the boys brought in his camera to take pictures of the terminal leaves of the tomato plants, to address the problem the team members had in determining changes in growth. At this point the interactions of the group members would be labeled constructivist according to the continuum below:

What is the nature of the small group work?

Environment	Characterization	Example
Constructivist	Students help determine the direction of their investigation; students look to group members instead of mainly to the teacher for ideas	After brainstorming in their group, students choose to investigate acids and bases in their homes. They independently decide among themselves which household substances to test, how to design the investigation, and how to carry it out

Negotiation of understandings

In a community of learners students negotiate understandings by debating their ideas of science content and real-world issues with others in the classroom. The dialogue is characterized by an active participation by the members of the group. Dialogue that fosters collaborative interactions would involve teacher and students exchanging ideas about the meaning of the science concepts versus focusing on the exact words used in the textbook definition. During the third week of the instruction, I involved my students in a parts per million lab activity. Although all the students appeared highly engaged in the activity, they had limited collaborative discourse. The students carefully used droppers to measure out solution into the wells of plastic trays. The students were so focused on the procedures of the activity, that the discussion never moved from lower level talk to negotiating the concepts illustrated by the lab: concentration and context. The team discourse fell short of my objective to have the students cognitively engaged in debating important science concepts. During this segment of the instruction, the students worked intently on completing the activity. However, the negotiation of ideas would be labeled *traditional.*

What is the nature of the dialogue?

Environment	Characterization	Example
Traditional	Students do not ask unsolicited questions; teacher tells students his/her interpretations; dialog related to procedures of the task/lab activity; students appear passive during the lesson	Students discuss the correct procedure for using pH paper and how to label the cups in testing the acidity of some solutions; students concerned mainly with completing the task

Public Sharing of Ideas

Public sharing of ideas refers to whole class discussions of science concepts and issues initiated by the teacher or the students. This more structured setting contrasts with the informal conversations that may occur during small group work at team tables. In scientific communities examples of public sharing include project meetings during which members give preliminary results of experiments. Late in the second week of instruction, a public sharing session involved the students in debating important issues and relating these issues to science concepts. An accident had occurred on a highway exit ramp near the school: a chemical tanker had overturned, spilling some of the contents. The event caused a school bus to become trapped in a traffic jam along with parents returning home from work and bringing students home from school. The next day several students ran into class, asking me to talk about the spill in class. In discussing the spill, the students recounted the accident and evaluated the potential hazard on the community. The students actively engaged in reconstructing the series of events and attempted to assess the impact of these events on the environment. As soon as one student finished talking, another would offer information. This engagement contrasted sharply with the passive response of the students in a previous class discussion on chemical and physical changes. During this lesson, the nature of public sharing would be labeled *constructivist* according to the continuum below:

What is the nature of the reporting of ideas?

Environment	Characterization	Example
Constructivist	Students share their own ideas publicly with other members of the class for feedback and revision	Students publicly share ideas of setting up an investigation of the effect of asbestos on plant growth; other students in the class question the experimental design, and suggest a better, and safer means of setting up the investigation

Collaboration With Experts

In traditional classrooms the main sources of information are the textbook and the teacher. In a community of learners, members extend the boundaries of the classroom by including resource people outside the classroom walls. Students collaborating with experts in a constructivist manner would seek help and information through personal contacts, and even share their own findings with experts. Beginning in weeks 5-7 of the instruction, I helped my students access an electronic (E-mail) bulletin board called LabNet, an area on the commercial network, America On-Line. This bulletin board, developed by the Technical Education Research Center, is staffed by scientists and science educators and is used by teachers of other project-based classrooms (Roup et al., 1993). All the teams posted inquiries of their poisons, and used the E-mail responses to add their knowledge base of their poison, or to refine their experiments. One of the E-mail responses received by the team studying smoking and tobacco caused such a reaction that the team members pleaded with me to share the content of the message with the class. The contents of the message included reference to a recent newspaper article that stated that under mounting pressure from critics, the tobacco industry released a list of 599 chemicals added to cigarettes, including such additives as insecticide, methoprene, and ammonia. One of the members of the team read the E-mail message to the class, and asked for their classmates' responses. During this lesson, the nature of collaborating with experts would be labeled *intermediate* according to the continuum below:

What is the nature of collaborating with experts?

Environment	Characterization	Example
Intermediate	Students seek help and gain information from experts outside the classroom from personal contacts or on-line networking	A group of students post an e-mail message on an electronic bulletin board asking for the latest information on carcinogens in tobacco. A scientist sends some recent information over the network

Shared Responsibility for Learning and Teaching

Shared responsibility for learning and teaching involves students taking responsibility for their own learning. In a community of learners the teacher and students collaborate, generating interpretation by working together. In some cases, the student may take on the role of the teacher, either in small group or large group settings. In traditional classrooms, the authority remains with the teacher, and this interchange of roles relating to teaching and learning rarely happens. Beginning in week 5-7, Bobby became interested in the use of telecommunications. Peter, another boy in the class, asked Bobby to teach him how to access the bulletin board. Bobby and Peter began asking to come to the classroom during lunch instead of the cafeteria. Once they figured out how to upload the team letters, they taught me. Throughout the reminder of the instructional period, Bobby served as telecommunications expert and main uploader and downloader of E-mail for the teams in his class. Bobby would either distribute messages or would facilitate other team members in accessing them. Sometimes Peter would share this responsibility. Peter and Bobby shared in each team's enthusiasm when receiving mail, and they continued to come to the classroom during lunch, often bringing students from other classes. During these events of accessing and distributing messages, the nature of sharing responsibility for learning and teaching would be labeled *constructivist* according to the continuum below:

What is the nature of the instructional roles of the students and teacher?

Environment	Characterization	Example
Constructivist	Teacher facilitates the students in gaining responsibility for their own learning; Teacher and students generate interpretations by working together; Students teach other students/and the teacher	Teacher enables students to collect data on concentrations of chlorine in the school drinking water and compare this to chlorine levels which are hazardous; students share their finding with the class and teacher

Discussion and Implications for Research and Teaching

The focus of national reforms on inquiry and collaboration necessitates careful study of the processes involved in creating these kinds of learning environments.

The implications of examining student and teacher interactions and looking critically at the new roles of teachers and students in a community of learners could inform researchers and teachers in how to create these kinds of learning environments.

I used a process of researching the literature and action research to explore the critical components of a community of learners in my middle school science classroom.

The systematic application of the constructed rubrics of the collaborative components served to highlight events during my instruction that influenced students in actively engaging in substantive interactions. The two components in the framework that appeared critical in moving my classroom towards a community of learners were first, the authenticity of the tasks, and second, the connection with experts outside the classroom. When the lab activities were connected to topics rather than to the student-generated investigations, the student interactions consisted of following procedures rather than negotiating understandings of important concepts. However, when activities were situated in real-world contexts, the students engaged in collaborative interactions. When students connected to experts outside the classroom, students increased the thoughtfulness of their conversations and sharing of ideas. Using the rubrics also revealed segments of lessons that did not exemplify a community of learners ; instruction that was teacher-centered versus student-centered and topic-driven rather than inquiry-driven.

Creating a community of learners in my science classroom did not occur smoothly. This kind of teaching, in which students are given the freedom to make choices in designing investigations and to grapple with ideas by debating with peers, is difficult. Teaching is complex; classrooms are complex. Therefore by isolating important features of a learning community and providing vignettes of classroom events to illustrate these components, teachers and researchers may be able to critically determine the extent to which a classroom resembles a community of learners fostering inquiry. This community depends on the teacher and students taking on roles that contribute to the negotiation of understanding of the science content, and to finding answers to the questions generated by this community. The roles of the teacher and students are critical to creating and maintaining a community . "The idea of a community of learners is based on the premise that learning occurs as people participate in shared endeavors with others, with all playing active but often asymmetrical roles in sociocultural activity" (Rogoff, 1994, p.209).

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DEVELOPING AND ACTING UPON ONE'S CONCEPTION OF SCIENCE: THE REALITY OF TEACHER PREPARATION

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Introduction

Recent reforms in science education have placed increased emphasis on helping students develop an understanding of global, integrating themes (e.g., equilibrium, evolution, and systems) as opposed to placing primary emphasis on developing specific factual knowledge (AAAS, 1993, NRC, 1996). Although the specific recommendations of each of these reform efforts differ to some degree, emphasis on developing students' understanding of the nature of science (NOS) is clearly a common theme. This should not be surprising since this educational outcome has been a concern since 1907 (Lederman, 1992).

Despite the longevity of the concern about students' understanding of the NOS, progress toward the goal remains disappointing. Research has consistently shown that students' and teachers' views are not consistent with contemporary conceptions of the NOS (Duschl, 1990; Lederman, 1992, among others). Recent research has focused on teachers' conceptions of the NOS and avenues to help them develop desired understandings (Aguirere, Haggerty, & Linder, 1990, Brickhouse, 1989, 1990; Brickhouse & Bodner, 1992; Bloom, 1989; Briscoe, 1991; Gallagher, 1991; King, 1991; Koulaidis & Ogborn, 1989). This line of research is based on the assumption that teachers' conceptions directly translate into their teaching practices. This assumption, while intuitive, has not been validated (Lederman & Druger, 1985; Lederman & Zeidler, 1987).

In fact, a growing body of research indicates that the relationship between teachers' conceptions and their classroom practices is far from being direct or simple. For instance, Gess-Newsome and Lederman (1995) found that the translation of experienced high school teachers' conceptions of their subject matter into their teaching could be direct, limited by other variables, or absent. The authors identified six variables that seemed to mediate such translation, including teacher intentions, content knowledge, pedagogical knowledge, students' needs, teacher autonomy, and time. Additionally, Smith and Neale (1989) reported that elementary science teachers' content knowledge, as well as their concerns with classroom management and organization, were significant factors in translating their beliefs about science into classroom practices.

Similar results are evident in research focused on the translation of teachers' conceptions of the NOS into classroom practice. In general, these studies have indicated that the relationship between teachers' beliefs about the NOS and their classroom practice is more complex than originally imagined. Several constraining factors have been reported, including pressure to cover content (Duschl & Wright, 1989; Hodson, 1993), classroom management and organizational principles (Hodson, 1993; Lantz & Kass, 1987; Lederman, 1995), concerns for student abilities and motivation (Brickhouse & Bodner, 1992; Duschl & Wright, 1989; Lederman, 1995), institutional constraints (Brickhouse & Bodner, 1992) and teaching experience (Brickhouse & Bodner, 1992; Lederman, 1995). Thus, the results of these studies are consistent with Lederman and Zeidler's (1987) conclusion that "a teacher's classroom behavior does not necessarily vary as a direct result of his/her conceptions [about the NOS.]" (p. 731).

Given the apparent complexity of the relationship between teachers' conceptions and their teaching practices, it should prove fruitful to explore preservice teachers' conceptions of the NOS and their translation into classroom practice. The purpose of this study was to elucidate the relationship of preservice teachers' conceptions of the NOS with their planning and student-teaching. The main questions of the investigation were:

1. What are preservice science teachers' conceptions of the NOS prior to student-teaching?
2. Do preservice teachers emphasize the NOS in their planning and/or teaching?
3. What are the factors that explain preservice teachers' emphasis on the NOS in their teaching?

Method

Sample

Fourteen preservice science teachers, nine male and five female, participated in the study. Participants were enrolled in a fifth-year MAT teacher preparation program in a rural state university and were seeking certification in secondary level science. All participants had earned BS degrees and seven had earned MS degrees in their disciplines prior to joining the program. During the year of teacher preparation the preservice teachers were involved in several campus-based university classes that directly related to science teaching (e.g., Secondary Science Methods and Strategies, Microteaching, Curriculum, Science Pedagogy), and student-teaching. It is noteworthy that the program places emphasis on the NOS, its central role in the reform efforts, and its implications for teaching science in the classroom.

Procedures

Data collection was continuous and spanned the entire calendar year that the participants were enrolled in the program. Several data sources were used to answer the questions of interest. Following the summer coursework in science methods, but prior to student-teaching internships, the preservice teachers were administered a questionnaire to assess their conceptions of the NOS. This questionnaire consisted of seven open-ended items and was intended to be used in conjunction with follow-up interviews (Lederman & O'Mally, 1990). The aspects of the NOS assessed were: the tentative and empirical nature of science, subjectivity, creativity, and the role of social and cultural contexts in science, observation versus inference, and the functions and relationships of theories and laws. The questionnaires were not analyzed until the end of the data collection process to avoid biasing other phases of data collection and/or analysis.

The researchers collected copies of all participants' daily lesson plans for the 12 week student-teaching, as well as classroom videotapes, and supervisors' clinical observation notes. Each participant's portfolio, a requirement for the completion of the MAT program, was also used as a data source. Portfolios consisted of two full units (12 to 16 days each) of instruction, including rationales, goals, objectives, lesson plans, assessment instruments, reflections on the success of individual lessons and the unit as a whole, and videotapes of classroom instruction. These data were searched for evidence that the preservice teachers planned for and/or taught the aforementioned aspects of the NOS during their student-teaching. The specific instances, whether explicit or implicit, in which participants addressed the NOS in their planning were documented. Instructional objectives, and/or activities that overtly addressed one or more aspects of the NOS were taken to be explicit instances. Implicit instances, on the other hand, represented references to aspects of the NOS inferred from less prominent parts of the lesson plans such as isolated statements inserted into an instructional sequence. Activities that were consistent with a particular view of science, but did not explicitly focus students' attention on the NOS were also considered to be implicit instances.

Data Analysis

Prior to data analysis, the researchers independently analyzed three identical, randomly selected samples of each of the data sources. Results of these analyses were compared in order to establish inter-rater agreement on the aforementioned system for identifying instances of the NOS. Better than 90% agreement among the three researchers was achieved for explicit references to the NOS. Identified instances of implicit references to the NOS were compared and discussed, but due to the subjective nature of the interpretation of these references, the researchers decided to focus subsequent analysis primarily on the explicit references to the NOS. Finally, the remaining collected documents and videotapes were distributed among the three researchers and analyzed for explicit references to the NOS.

Following the analysis of portfolio and instructional materials data, preservice teachers were interviewed during their final term (following student-teaching) of the MAT program. These semi-structured interviews were conducted to validate responses to the NOS questionnaire and generate in-depth profiles of the participants' views. The interviews were also used to verify and corroborate the previous analysis of the other data sources. A core set of questions guided the interviews:

1. What do you think are the most important things to emphasize in your teaching? Why?
2. What in your opinion is the NOS? What makes science different from other disciplines of inquiry (religion, philosophy, etc.)?
3. (At this point interviewees were provided with their questionnaires, asked to familiarize themselves with their earlier responses, and to comment on and clarify these responses.) What did you mean by your response to question number (1-7)?
4. Do you think that teaching the NOS is important? Why? (or Why not?)
5. Did you teach the NOS? If yes, how? Why did you teach the NOS in that particular way? (If not, why?)
6. Did you do enough? Can you elaborate?
7. Did your students learn the NOS? How do you know? Did you assess your students' understanding of the NOS? How did you do that?
8. (The participants were then provided with evidence from the analysis of their lesson plans, work samples, and videotapes and asked to comment on any discrepancies between what they said they did and what was in their plans and portfolios.) On reviewing your lesson plans, I observed that you did not (or did) do much with the NOS. Why?
9. I did not (or did) observe that you assessed understanding of the NOS? Why? (or Why did you assess understanding of the NOS in that particular way?)
10. How will you deal with the NOS when you have your own class?

The typical duration of an interview was one hour. Digressions were common, and the participants' lines of thought were followed and probed in depth. All interviews were audiotaped and transcribed for analysis.

Results

Conceptions of the Nature of Science

Analysis of responses to the open-ended questionnaire, as validated in the interviews, indicated that participants' views of the NOS were, in general, consistent with contemporary conceptions of the scientific enterprise. Most of the preservice teachers demonstrated adequate understandings of the empirical and tentative nature of science, and the role of subjectivity and creativity in science. However, their understandings of the relationship between theories and laws, and the distinction between observation and inference, even though discernible, were not well articulated. Moreover, participants failed to explicate a role for social and cultural factors in the construction of scientific knowledge and often confused the processes of science with aspects of the NOS. These conclusions are elucidated and supported with quotations in the paragraphs that follow.

That science is empirically based was emphasized by all participants. In fact, this aspect was dubbed essential in differentiating science from other disciplines of inquiry such as religion and philosophy. Tentativeness was another aspect of the NOS that was clearly explicated by all student-teachers. All categories of scientific knowledge including 'facts', hypotheses, theories and laws were believed to change.

> Things that at one point were considered to be facts are not now taken to be so. Theories do change, science is tentative . . . even laws change. (T # 1)

The tentativeness of science was intimately linked with its empirical nature. In fact, the collection of new data and the accumulation of counter evidence were cited as the major reasons for the modification of scientific constructs:

> Science is tentative [and] subject to change by virtue of collecting new data. (T # 1)
>
> The knowledge base of science is always challenged, refined, and changed . . . by doing empirical observations and experimentation. (T # 14)
>
> Even complete theories have to be altered to make them more consistent with new observations. (T # 7)

Participants also advanced subjectivity and creativity as factors that contribute to the tentative nature of science:

> Tentative means that even though you try to exclude personal bias, you never can completely, so results and conclusions are tentative. (T # 5)

The view that science is a completely objective and rational activity was dismissed by the participants. Subjectivity, creativity, and imagination were advanced as integral to scientific investigation. Subjectivity, including the individuality of scientists, their backgrounds, and beliefs, was thought to play a major role in interpreting data, drawing inferences, and formulating conclusions:

> Even though rational and objective inferences are supposed to be drawn from data . . . irrational and subjective elements due to human nature are at play . . . different scientists are people and have different viewpoints . . . their own preconceived notions and expectations get into the interpretation of the data . . . imagination is necessary for making inferences out of data. (T # 1)
>
> Science is not purely logical, there are tons of things that come into play . . . and if [a theory or hypothesis] is your baby, your life-long work, you don't want to give it up, it hurts. (T # 4)

Creativity and imagination were given equal weight in scientific investigations, especially in determining research methods:

> There is no one method of doing science. In developing their methods scientists use imagination and creativity. (T # 1)

And even though all participants ascribed a role for creativity and imagination, they differed as to the stages at which these factors come into play in scientific investigations. Some thought that "there is creativity before and after data collection," (T # 7) others thought that they "don't see how you can be creative in collecting data. After data collection, sure it is creative. It takes a little imagination to determine which route to follow." (T # 8) Still others believed that "there is a creative aspect to science, especially when developing hypotheses . . . but when you test a hypothesis, this moves you [to using] accepted, logical ways of testing." (T # 1)

An understanding of the distinction between observation and inference was not evident in the case of many participants. Moreover, even though some of the preservice teachers clearly delineated the distinction between scientific theories and laws, many failed to articulate that distinction. That laws are statements or descriptions of discernible patterns in observable phenomena and that theories are inferred explanations for those phenomena, was not evident to many participants:

> I can't nail down the difference between theories and laws . . . Laws seem more established and this is the only difference I can see. (T # 14)
>
> Laws are more global, bigger . . . there should be a clear way to distinguish [theories and laws] but I can't think of one. (T # 5)

A few even expressed a simplistic, hierarchical view between these constructs in which theories become laws depending on the availability of supporting evidence, thus failing to recognize that theories and laws are different kinds of knowledge:

> A law is a supported theory. A theory is a proposed idea or application. (T # 8)

Finally, the effects of the social and cultural context in which scientific investigations are embedded were mostly overlooked and at best poorly articulated by the participants. Moreover, some of them confused scientific processes with aspects of the NOS. When asked in the interview what they thought the NOS was, some participants gave responses similar to the following:

> Science has a set of processes: observation, experiments, and trying to draw conclusions and connections. (T # 3)
>
> There are two important aspects to science . . . one is the development of a hypothesis . . . . The second is coming up with a way to test the hypothesis. (T # 1)

In summary, although the 14 participants' had not mastered all seven aspects of the NOS that the MAT program emphasized, they were able to demonstrate adequate understandings of the tentative, and empirical aspects of the NOS, as well as the roles of subjectivity and creativity.

Planning for and Teaching the Nature of Science

When asked, toward the end of the interviews, whether teaching the NOS is important, all but two participants answered in the positive. Several justifications were provided. Many thought that teaching the NOS makes learning science more interesting. Others advanced that teaching the NOS is imperative because it cannot be separated from the content of science. Others argued that science as 'a valuable way of thinking' can only be conveyed to students by teaching the NOS. Still others thought that teaching the NOS is a safeguard against dogmatism, necessary for making decisions regarding scientifically related societal issues, or that it reinforces the learning of science process skills.

However, analysis of the participants' lesson plans showed rare evidence of planning to teach the NOS. There were a small number of references to the NOS in a few of the participants' plans.

These instances, however, were isolated, lacked focus, and generally addressed a single aspect of the NOS. Only two participants had planned lessons that specifically addressed the NOS. One participant had two separate lessons that focused on explicating the role of hypotheses and models in science and featured the use of a few activities and demonstrations geared toward that end. The other participant had planned a single lesson in which he used the same demonstrations initially presented in the MAT program to help his students distinguish between scientific observations and inferences. However, when asked about this lesson in the interview, he replied:

> That [lesson] is the demos thing. I don't consider that this is teaching the NOS, but I did it anyway . . . I don't believe that this is the best way to do it. (T # 3)

The apparent dissonance between the importance of teaching the NOS as emphasized by most of the participants, and the scarce attention they accorded the NOS in their instructional planning is intriguing and worthy of further discussion. It is possible that the participants anticipated the researchers' interest in the NOS. The question of whether it was important to teach the NOS, as previously noted, was asked later in the interview. At that stage the participants were already aware of the interviewers' focus, and might have responded accordingly. The plausibility of this explanation is increased by the fact that one of the researchers placed explicit emphasis on the NOS and how to teach it in two MAT courses in which the participants were enrolled, while another researcher supervised many of the participants and often discussed the NOS with them. However, the first question on the interview --before the theme of the NOS was brought up, asked the preservice teachers to delineate the things they thought were most important to emphasize in their teaching. In responding to this question, 11 of the 14 preservice teachers did not list the NOS as a topic they would emphasize in their teaching. Many other aspects were ascribed more importance. Students' needs and interests figured prominently in what participants' thought was important to teach.

Participants thought their primary goal would be to secure a safe learning environment that would sustain students' interest in learning science. The aspects advanced as essential included combinations of the following: helping students develop generic reasoning skills such as synthesis, evaluation, and creative thinking; developing students' social skills such as communication, cooperation, self confidence, and respect for others; developing students' science process skills and their skills in using scientific equipment; teaching science content with less emphasis on factual knowledge and increased attention to mechanisms, interrelationships, and applications. The science content and applications emphasized were those deemed necessary for making informed scientifically-related social decisions and developing job related skills. Thus, when directive questions and cues were absent participants --with three exceptions, did not ascribe any importance or priority to teaching the NOS in their classrooms. Even the three preservice teachers who thought that teaching the NOS was important listed this goal only third or fourth. It seems that the preservice teachers did not internalize the importance of teaching the NOS.

An additional factor that might account for the discrepancy between the participants' emphasis on the importance of teaching the NOS and the scant attention they accorded this aspect in their teaching relates to the participants' views on how to teach the NOS. When asked whether they taught the NOS in their student-teaching, 12 out of 14 participants said they did. However, analyses of the supervisors' field notes and the preservice teachers' videotaped lessons during student-teaching revealed that the participants actually addressed the NOS in their teaching much less than they had claimed. As it turned out, although the MAT program consistently emphasized that the NOS needed to be explicitly addressed, the few cases where participants reported teaching the NOS involved instances where students were simply "doing science." Either the preservice teachers were not really emphasizing the NOS, or they believed that students could learn it implicitly.

It is interesting to note that participants were shown a minimum of eight activities (including content embedded activities) in their Science Methods class specifically designed to teach the NOS. Yet, despite the program's emphasis on how to teach the NOS, most of the preservice teachers indicated that they needed more activities before they could adequately teach the NOS:

> The NOS wasn't strongly emphasized . . . because I didn't have enough resources to do many demos of the NOS. (T # 10)

Moreover, all participants, including the few who claimed to have taught the NOS explicitly, were unsure whether their students learned anything about the NOS. None of the 14 participants reported formally assessing students' understanding of the aspects of the NOS that they believed they had taught. Again, there appears to be a significant discrepancy between these preservice teachers' stated belief in the importance of teaching the NOS and their failure to formally assess it.

To sum up, even though questionnaire and interview responses revealed that all participants had adequate understandings of several important aspects of the NOS, most gave little attention to planning, teaching, and evaluating their students' understandings of the NOS. Participants' justified this discrepancy between their beliefs and instructional practices during the interviews by appealing to several constraining factors.

Constraints on Teaching the Nature of Science

Participants viewed the NOS as less significant than other outcomes such as students' needs and attitudes, and science content and processes. Moreover, given their preoccupation with classroom management and routine chores, they accorded less attention to teaching the NOS. Second, they expressed discomfort with their own understandings of the NOS. Third, they noted the lack of resources and experience for teaching and/or assessing understanding of the NOS. Finally, they noted the constraints related to the nature of student-teaching especially the restraints placed upon them by their cooperating teachers.

As mentioned earlier, when given freedom, most participants did not give priority to teaching the NOS. Students' needs and interests were important factors in deciding what should be emphasized in the classroom as evident in the following representative quotation:

> I think kids are not interested in the NOS itself . . . For me it is important to do with kids things that are important to them, that somehow they can buy into it, and you know, say this is important and I want to learn this . . . I don't plan to teach the NOS . . . I don't think it is something that I would spend a great deal of time on. (T # 14)

Others thought that teaching content had precedence to teaching the NOS:

> Getting the knowledge base is more important than the NOS. I have to stick to content knowledge. (T # 7)

Many other preservice teachers explained that they are not confident enough in their abilities to efficiently manage their classes as beginning teachers, let alone having to worry about teaching the NOS:

> When I'm confident enough how to run the classroom environment and all of that, and I feel confident in the school environment, and have all other things under control so I don't have to worry about the day to day process of just surviving, I think I will come up with more activities to promote the NOS. (T # 7)

Many participants also expressed their discomfort with their own understandings of the NOS and their ability to assess student understanding of a topic to which they were first introduced in their MAT program.

> I didn't do much with [the NOS], maybe due to a lack of my understanding . . . I struggled enough just to get lesson plans done, I didn't know how, or how to make it easy enough to make it worth my own time. How can I teach it if I don't quite get it yet . . . it takes a lot of processing things that you're given for the first time. I went through four years of undergraduate studies with no NOS, and none in high school either. (T # 8)
>
> I couldn't really assess the NOS, because I don't really know what the NOS at the high school level is. (T # 7)
>
> I was not prepared to teach the NOS. (T # 3)

The lack of resources and materials was another reason given for not teaching the NOS:

> I did not have enough materials to do many demos of the NOS . . . I have a couple of resources from journals. (T # 5).

A final important factor was the nature of student-teaching experience. Participants explained that they had to cover the content that their mentor teachers had assigned them within predetermined time limits. They felt they were given no choice in deciding what their students should learn:

> No, the NOS was not emphasized because of how things are driven in the school, you have a certain amount of things in a certain amount of time . . . I had to keep up with my mentor since I couldn't teach radically different stuff. (T # 5)
>
> I had material that I needed to cover. I had content more in mind that the NOS. I had to emphasize content, which is not necessarily how I like to teach it. (T # 1)
>
> For one, it was not an ideal situation for me to do the NOS the way I wanted to. Student teaching is an artificial situation, I don't have complete freedom to do what I want . . . I did not have the opportunity to do what I exactly wanted to do . . . you teach what the mentor teacher would like for you to teach. (T # 4)

Discussion and Implications

Consistent with previous research it seems clear that teachers' conceptions of the NOS do not necessarily influence their classroom practice (Brickhouse, 1990; Duschl & Wright, 1989; Hodson, 1993; Lederman, 1992; Lederman & Zeidler, 1987). Indeed, this was the case for the majority of the 14 participants who all possessed views of the NOS consistent with current reforms.

Teacher preparation, no doubt, has a direct impact on the successful implementation of the reform efforts in the science classroom. As far as the NOS is concerned, efforts have focused on helping preservice teachers develop adequate understandings of the NOS. The results of this study suggest that although understanding the NOS can be thought of as a necessary condition, it nevertheless is not sufficient. The crucial translation of preservice teachers' conceptions of the NOS into classroom practices needs to be reinforced by the culture of teacher preparation. To start with, teacher preparation programs should help prospective teachers develop an understanding of the rationale behind, and a comprehension of the importance of emphasizing the NOS in their teaching that goes beyond the customary discourse. Preservice teachers should be able to justify for themselves the importance of stressing the NOS, and to derive a framework in which the NOS accords with and reinforces other aspects that they believe are worth teaching (e.g., student attitudes and science content). Second, preservice teachers should be given much more extensive experience in teaching and assessing the NOS. Such experiences should be based on practical understandings of how students learn and what it takes to modify instructional activities to reinforce developing adequate understandings of the NOS. Every effort should be taken to insure that student teaching serves to reinforce the above focus, rather than undermine it.

Third, preservice teachers should have planned opportunities to teach the NOS in their internships as opposed to it being left to chance or to the discretion of mentor teachers. Most importantly, it should be emphasized that explicit attention to the NOS is essential (Lederman, 1995). Extensive effort should be made to help teachers avoid the apparent tendency to think that the NOS can be taught implicitly through student participation in science activities.

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BARRIERS FOR HISPANICS AND AMERICAN INDIANS ENTERING SCIENCE AND MATHEMATICS: CULTURAL DILEMMAS

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This paper includes two sections. In the first section, one author discusses the growth of the U.S. Hispanic population and the barriers faced by Hispanic students entering science and mathematics in our educational system. In the second section, the other author discusses the American Indian population and factors which affect the success of American Indians in science. Both authors emphasize the role of culture and obstacles faced by K-12 students when their culture conflicts with the majority culture.

Barriers for Hispanics Entering Science and Mathematics

by Katherine I. Norman

Comparing beliefs of teachers and parents provides insight into cultural dilemmas faced by minority students in majority schools. Divergent convictions are illustrated with quotes from a Texas teacher and a Latino Parent:

> From the teacher "The parents never come to school and they don't teach respect in the home. Why, the children won't even look me in the eye when I talk to them."
>
> From the parent "Respect is the most important thing is what I tell my kids. Don't make trouble, don't ask questions, and look down when the teacher talks to you."
>
> (Hodgkinson & Outtz, 1996).

Hispanics demonstrate practices similar to many other "non-majority" groups. Showing respect for elders and authority figures by looking at the floor and being silent when in the presence of teachers is taught as proper etiquette by many minorities, and yet is considered a sign of disrespect by traditional white America.

Other differences in the cultural values of Hispanics and "mainstream" America include the practice of "putting yourself forward." This is considered a step toward excellence by many

Americans, but is not taught or even considered by Hispanics. Many of the differences and conflicting values end up being barriers for Hispanics, and prevent them from succeeding in their educational and career endeavors. The recent increase in the U.S. Hispanic population and barriers which prevent the Hispanic population from succeeding in science and mathematics are discussed in this section of the paper.

Hispanics in the U.S.

The U.S. Bureau of the Census lists four racial categories (American Indian/Alaskan Native, Asian/Pacific Islander, Black and White), and only one ethnic group which is Hispanic. The Hispanic ethnic category exists only in this country. The term "Hispanic " was coined as a catch-all category to cover many national and regional groups. Hispanics may be of any race and are divided by geography, country of origin, class, group differences, and the time and circumstance of their entry into this country. "Hispanic" is the term normally used in the Eastern part of the U.S. "Latino" or "Chicano" is the preferred term in California, and "La Raza" is preferred by some and means from Mexico and Central America (Hodgkinson & Outtz, 1996).

Hispanics usually think of themselves in relation to the county from which their ancestors came. The largest Hispanic groups in the U.S. are Mexican Americans, Puerto Ricans, Cuban Americans, and Central and South Americans. The U. S. Hispanic population is increasing rapidly, with Texas and California leading the nation in percentages of Hispanics. Between 1980 and 1990, the Hispanic population grew seven times as fast as the rest of the U.S. population, increasing by 53%. By the year 2010, the U.S. Hispanic population is expected to number 39.3 million, compared to the expected African American population of 40.4 million. By 2015, Hispanics are expected to outnumber African Americans 44 million to 43.1 million. The increase in the Hispanic population is due to several factors: a high birth rate (26/1000 women in 1993), substantial immigration over the past several decades, and the tendency of Hispanic females to marry and have children early.

There are approximately 800,000 migrant farm workers in the U.S., 94% of whom are Hispanic and 80% of whom were born in Mexico. These Hispanics have the lowest graduate rate of any population in the U.S.; many leave school after the sixth grade. They spend little time discussing positive educational experiences with their children, primarily because they have had few such experiences. The life expectancy of a migrant worker is 49, compared to 75 for other citizens. Repeating cycles of ignorance, lack of self-respect, menial job skills, poor medical care, poverty and early pregnancies dominate migrant communities (Hodgkinson & Outtz, 1996).

The Hispanic Educational Pipeline

The educational pipeline for Hispanics is partially closed at the bottom where the youngest children enter, due to immigration, low family income, lack of parent education, limited English and job skills. Forty percent of Hispanics leave school before the spring of their sophomore year, and 56% of Hispanic adults are functionally illiterate. In 1989, only 16% of 18-24 year old Hispanic Americans were enrolled in college, and they continue to be vastly underrepresented in graduate programs. States with the highest drop-out rates for Hispanics include New York (62%), Texas (45%), and Illinois (47%) (Schuhmann, 1992).

Barriers for Hispanics to Science and Mathematics Studies and Careers

Barriers for Hispanics entering science and math are the same factors that cause their attrition from formal schooling. Many of these barriers can be traced to differences in their culture and in the majority American culture, and include (a) alienation of parents in the education process; (b) language; (c) income disparity and poverty (d) failure of the system to identify students in danger of dropping out; and (e) a shortage of role models in education as well as in the sciences and mathematics (Schuhmann, 1992).

Hispanics are divergent thinkers, yet many of our educational practices (particularly traditional assessments) call for convergent thinking. The learning preferences of Hispanics have been ignored, and Hispanics have been expected to "fit in" with the majority. Hispanics have had to fight unspoken values, and many Hispanic students have faced negative preconceived expectations from society and teachers. With an increase in immigration, the need for bilingual instruction has increased while funding for bilingual education has decreased.

Absence of Science and Math Encouragement and Opportunities

The author conducted a pilot study in a Southern California high school, inquiring about Hispanic students' personal beliefs and family values related to success in science and mathematics studies and careers. Results indicated that ninth and tenth grade Hispanic students have received limited encouragement from family members and teachers to pursue careers in science and math. Hispanic students were asked why their peers do not enter science and math programs. Their answers included the following:

"Parents discourage them."

"Students discourage them."

"Teachers discourage them."

"Low self-esteem"

"Background"

"Some people don't like math or science because they get bad grades."

"Program evaluators base their opinions only on grades instead of the actual persons potential."

"Some kids don't even think about it so they don't even care. Some kids don't know when programs are up. Some don't even care."

"Their lack of interest and that they're lazy."

"Work"

"Intimidation of not knowing all the material."

"Laziness, wrong teachers, no motivation."

"People find it difficulty, boring. Financial trouble."

"It's the money."

Recommendations for the Education of Hispanic Students

With all of the discouragement cited in the pilot study, the opportunity for Hispanics to enter science and math clearly seems restricted. Teacher education and parental education is necessary to provide opportunities for K-12 students to enter science and math programs. Other requirements for strong educational programs for Hispanics range from training in study skills to financial incentives and financial aid. Most importantly, students must be provided an environment that assures them they can succeed as scientists, mathematicians, and science/math educators. Mentors and role models are essential.

Other necessities include K-college linkages, family involvement, a curriculum that reflects the student's culture, and assessment practices which reveal what students know. Linkages should be established in elementary, middle and high schools, as well as in two and four year colleges. Families should be involved in the educational process: parents must be personally invited to participate in school activities. The curriculum should reflect students' languages, as well as their cultural backgrounds and experiences. Alternative assessment measures should be created to determine aptitude and success in educational programs.

Teachers need to develop and demonstrate an understanding of individual and group differences in learning styles and working habits. They should incorporate cultural elements into their teaching and pay attention to nonverbal communication, values, and communication patterns. Classroom management strategies must consider cultural, socioeconomic and linguistic factors. Instructional activities should be organized to build on ways in which students participate in discourse in their own cultures. Educators must recognize and honor the values and norms of the students' home cultures, and should recognize the legitimacy of and use the language of the students. Teachers and college faculty must be prepared to work with diverse students. Finally, students who can bring cultural understanding and sensitivities to teaching must be recruited into teacher preparation programs (Schuhmann, 1992). Only when our educational systems and programs provide for the strengths and needs of Hispanic students will these students succeed in science and mathematics.

Factors that Affect the Success of American Indian High School Students in Science

by Joseph F. Keating

American Indian high school students like many other minorities have generally performed poorly in science courses, taken fewer higher level courses and scored below average on tests of science understanding. Few have chosen to go on to higher education in science and therefore are also very underrepresented in science careers (Barba, 1994). In light of these and other similar statistics, it is essential that science educators assume responsibility and leadership in the effort to overcome the lack of success among students from diverse backgrounds like American Indians. One of the major themes of national reform efforts in science has been the democratic goal of raising the general science literacy of all Americans (Rutherford and Ahlgren, 1990). Identifying and focusing on appropriate science curricula and strategies that deliver effective science instruction for multicultural populations like American Indians should be an essential part of this goal. An important outcome of effective science preparation might be that scientifically prepared American Indian students could assume leadership roles on their reservations and in their communities in a variety of science related fields including medicine, the environment, education and technology.

This section will include specific factors that research results indicate may influence the success of American Indian high school students in science. These research results were based primarily on two studies on Navajo high school students conducted by the author:

1. an experimental study that compared student success in a traditional Biology course with one which infused tribal cultural components into the curriculum and strategies (Keating, 1996).
2. a correlation dissertation study that investigated a number of factors that might affect success of Navajo students in science (Keating, 1992).

These considerations are based broadly on these and other research studies, as well as extensive personal experience working with American Indian students (Keating, 1992; Keating, 1996 and Killackey, 1989). In addition to these findings, there are also corresponding implications for educators which will also be discussed.

Although there are obviously multiple factors that affect everyone's success in an academic setting, this discussion focuses on three broad influences that impact American Indian students: (a) the degree of traditionalism of the individual student; (b) the school environment including backgrounds of the teachers, strategies and curricula utilized; and (c) the socio-economic background of the students including per capita income, family educational background and general home environment.

The Effect of Cultural Traditions on Science Learning

American Indian languages have little or no correspondence to the technical language of science. American Indian students' native languages may often have conflicts with English in semantic, syntactic and graphic-phonic components which make effective use of scientific terminology and concepts more difficult. For example there are no corresponding words in Navajo for photosynthesis or inertia. Research results indicated that Navajo students achieve less and have lower positive attitudes in those science classes where teachers fail to recognize this and consequently do not make appropriate adaptations. The implication is that teachers who utilize strategies that link science terminology to native language will have more success with their students. Examples of some strategies used by teachers in more successful classrooms (i.e. where their students demonstrated greater success in science achievement and positive attitudes) were use of the four square model, visual aides and dual dictionaries and attendance at Navajo language courses. The four square model utilizes a poster format with four equal squares---one square has the English word, a second a hyphenated corresponding native language word, a third has an illustration of the term and the fourth a definition and (or) examples. Visuals include the use of posters, slides, video tapes, computer software or realia. Teachers who take at least some course work in Navajo (or other American Indian language) will learn to appreciate the differences between the languages and be more likely to make appropriate adaptations in their own classes (Keating, 1992).

Cultural taboos may cause conflict between some of the materials or concepts used in science . In the Navajo culture for example, dissection of frogs and some other animals is considered a taboo whose violation may result in severe consequences that only very elaborate ceremonials can offset. The presence of and (or) touching bones and other remains from humans and certain animals is also a serious taboo with serious consequences. There are also many others which have direct implications for the teaching of science (Keating, 1992; Bulow, 1972). The implication of this cultural tradition is that science teachers need to become familiar with common taboos through reading, cultural training and direct interaction with the community so that they may seek ways to modify, adapt or circumvent those situations which might present a conflict for their students. Examples of adaptations utilized by teachers in more successful classrooms included use of computer software for dissections, avoidance of topics related to taboos substituting equivalent but different concepts.

Behavioral expectations of teachers (non-Indian) for their students can cause conflict in the classroom. For example, in the Navajo tradition the role of the student is as a listener not an active, vocal participant. This is based on the cultural mores that a student respects the teacher by listening, not asking questions or responding as many non-Navajo teachers would expect from their students (Rhodes, 1988; Keating, 1992). Also, the common English response 'thank-you' is traditionally infrequently given probably due to the fact that the Navajo word for 'thank-you' (ahe'hee') is reserved only for extenuating situations. Appreciation for assistance, is however, often given in other less direct ways such as a small gift or invitation to dinner. The same considerations and implications that applied to taboos would apply to gaining an understanding of these types of cultural behavioral differences. Teachers who understood these and made appropriate modifications in their own personal responses to traditional American Indian behaviors tended to have more successful science classrooms.

The importance of reaching out to understand language and cultural differences cannot be over-emphasized. The research studies support the idea that students tend to respect and have greater rapport with those teachers who demonstrate this sensitivity, ultimately resulting in greater achievement and positive attitudes in science.

The Effect of the School Environment on Science Learning

Typical teaching styles observed on reservation high schools include a heavy emphasis on strategies such as direct instruction (lecture), use of textbooks as the primary source for information, individualized seat work and standardized short answer assessments. Although all of these more traditional strategies have some value in science instruction, an overemphasis appears to creates a mismatch with the typical learning styles of American Indians as well as for science students in general. For example, the research results lend support for the value of using a variety of strategies with some, in particular, being especially effective. More successful Navajo science students, as measured by increased problem solving, greater positive attitudes and similar content achievement (compared to teachers using more traditional strategies) tended to be in classrooms where teachers placed an emphasis on a variety of strategies. The most successful ones included these particular strategies: cooperative learning, field trips, computer simulations, hands-on activities, group projects and authentic forms of assessment (portfolio, journals and performance exams) (Keating, 1992, 1996 and Killackey, 1988).

It is interesting that all of these correspond to traditional American Indian learning and teaching. For example, American Indians traditionally learned in small groups by practicing a task over and over until it was mastered and then demonstrating this to the elder (application of cooperative groups and performance exams). Also, holistic concepts are integrated throughout the learning experience, such as, individual success is devalued compared to the importance of success of the group (group projects); the connection of learning in a natural setting as compared to a classroom (use of field trips) (Rhodes, 1988). The implications of this is that teachers should be trained in the theory and practice of these innovative strategies and encouraged to apply them in their science teaching.

Typical science curricula stress topics or individuals that make few connections to American Indians. Results from research that evaluated curricula that incorporated tribal science showed increases in self esteem and attitudes (Killackey, 1988) as well as problem solving, choice of courses and careers (science) (Keating, 1996; Keating, 1997)). In these studies tribal resources, materials and philosophy were connected to western science concepts. In this bicultural approach students used the tribal cultural contexts as a way to learn western science. Examples of topics used included the use of ethnobotany, archeoastronomy, animal husbandry and architecture. Tribal elders, parents and medicine-men were used as resources to teach students and assist and train teachers and served as appropriate science role models. Alternative texts and supplementary resources were also used (Killackey, 1989; Keating, 1995; Mayes and Lacey, 1989).

The important implication for science teachers is that it is crucial for them to seek curricular ideas and role models from their students. The teacher must become an active learner himself (herself) and be open to drawing a typically hesitant community and its resources into becoming an active participant in the instructional team. In this role it is important that the teacher is patient, humble and flexible in order to facilitate this change in the curricula.

Most of the science teachers that teach American Indians are non-Indian and lack formal or informal training in the culture of their students and the appropriate pedagogy to teach science to them. Ninety-eight percent of high school science teachers on reservations schools are non-Indian. This does not preclude effective science teaching. However, if there were more American Indian teachers they could assist the non-Indian teachers in overcoming some of the cultural conflicts discussed earlier. There is some evidence that American Indian students respond better in classes taught by American Indian teachers (Keating, 1991).

Because of the many conflicts that science as taught presents to the traditional American Indian student few choose science or science teaching as a career. This is starting to change as colleges and universities offer teacher training programs which emphasize the culture as a strength for learning. For example, Navajo Community College's Dine Philosophy of Learning or DPL attempts to incorporate elements of Navajo culture into all of the mainstream courses it offers. In addition, the college requires that all of its degrees including pre-service teaching include coursework in Navajo cultural studies as well as written and spoken Navajo. Many of these courses are also being taken by non-Navajo teachers at convenient satellite centers around the reservation. The University of New Mexico is offering an undergraduate education degree in Gallup, New Mexico which makes appropriate cultural connections. Because it is offered at convenient times this program is increasing immensely the number of Navajo teachers--some of whom will teach science. Using this as a model, other tribes should be encouraging educational institutes to provide opportunities for both inservice and preservice teachers to train in both appropriate cultural and pedagogical aspects of teaching.

The Effect of Socio-Economic Factors on Science Learning

American Indians typically live well below the poverty level--a factor which has an effect on all people regardless of ethnic, racial or cultural background. Low per capita income levels were found among the Navajo where 67% of families are below the poverty level and unemployment averages 40% (Keating, 1992). Many families do not have running water or electricity and also lack sufficient funds to provide proper nutrition for their children who typically have to spend many hours a week on buses. All of these are obvious impediments for students to function effectively in schools. Results from one of the studies indicated a strong association between family income and success in science achievement and attitudes. Although schools and individual teachers cannot solve all of these socio-economic ills they can assist in lessening effects of this economic gap. For example a few reservation schools have opened science labs, computer rooms, libraries and gymnasiums after school hours. They have provided resource people to assist parents and students in a variety of educational and health related activities. Some have also offered enrichment programs in science such as MESA (Minority Engineering and Science Association), the Odyssey of the Mind, Science Fair and Science Olympiad, which provide science experiences not normally available during the school day. To facilitate these after school functions, the schools have provided activity buses to transport students home----much like those previously offered only to athletes. Only a few schools are doing this, but these enlightened schools, administrators and teachers are to be commended and should serve as models to others. Without programs like these, few of these students would have access at home to books, computers, televisions, phones and other school resources.

Alcoholism on reservations results in a fairly large population of children with fetal alcohol syndrome (FAS) and fetal alcohol effects (FAE), both of which impact educational performance. Some estimates have been as high as 15-25% for the number of children born on the Navajo reservation with FAS or FAE. Since both produce effects that cause a variety of learning disorders it is important for science teachers to address the issues of alcohol abuse and its biological effects on developing fetuses within their curricula. Public health hospitals, individual doctors and tribal officials involved with drug and alcohol abuse are all good resources for the science teacher. The science teacher using appropriate strategies to present this topic can have an effect on student perception of the use and abuse of alcohol and perhaps make their students more cognizant of the dangers thereby ultimately reducing the number of FAS and FAE students in their own classrooms.

Most American Indian students from this present generation are the first in their families to seek a higher degree. Research results found that few of the parents in the study had higher education degrees with a fairly high percent not having completed high school (Keating, 1992). Only about 5% of Navajo students entering college complete a four year degree within six years with very few of these in a science or technology field (Willeto, 1991). This is compared to the national average rate of completion of about 50%. It is therefore vital that high schools encourage the parents to take an active role in the education of their sons and daughters. Encouragement and support from home is the number one predictor of success in College among American Indian students (Willetto, 1991). Schools and individual teachers can play an active role in this process. As discussed earlier the American Indian community can play a tremendous role in the curriculum as a resource for the teachers. This can also play a dual role of drawing parents and individuals to the school and making them feel welcome in this setting. Other formats in which parents were encouraged and become involved in the (science) education of their children included as coach/advisors in the Odyssey of the Mind program--an international, interdisciplinary problem solving program and as mentors/judges in science fair competitions. Another science related program which encourages parents to become actively involved within the school include Math, Science and Beyond ---a family hands-on science and math evening program (Solana Beach Elementary School District, 1990).

It is suggested that there is a much greater potential for American Indian students success in science when their parents are presented with opportunities that welcome and encourage them to become actively involved with the schools through collaborative teaching, mentorships and participation in science programs.

Conclusions

Based on research results and personal experiences in teaching American Indian (especially Navajo's) it was concluded that a variety of factors have an effect on the success of high school students. These factors were categorized into three major areas: (a) the degree of traditionalism of the individual student; (b) the school environment; and (c) the socio-economic background of the students.

Impediments to success in each area were noted with corresponding implications and suggested recommendations for science teachers and their schools. It was suggested that the tremendous cultural wealth of American Indians could be strongly linked to high school science programs as a resource. Using a bicultural linkage of the curriculum to the community will provide a basis of support and encouragement for the students attending these schools increasing the potential for success in science.

It is critical that the science education of American Indian students be improved. Tribes need members that include those that are science literate, as well as active, knowledgeable participants in science leadership roles as they continue to grow in the areas of technology, the environment, medicine and other science related areas.

Schools and the American Indian communities should consider some of these suggested recommendations and based on their own perceived needs, develop site based plans that attempt to incorporate some of the ideas.

Overcoming Common Barriers

There are many common barriers faced by Hispanic and American Indian students entering science and mathematics. These are often created by conflicts between the traditional culture of the these students and the methods typically used in teaching in K-12 science and mathematics.

Examples of common barriers to their success and potential career opportunities include language impediments to the learning of the technical language of science and mathematics, cultural taboos related to specific scientific activities, income disparity and poverty, and a shortage of mentors and role models in education as well as in the sciences and mathematics. Because of these and other related factors, young Hispanic and American Indian students have had a common absence of positive experiences and successes in science and mathematics at the early grade levels that has resulted in a correspondingly negative attitude about these fields. In addition, many Hispanics and American Indian students have not received encouragement or opportunities to excel in traditional science and mathematics careers.

Hispanic and American Indian parents and their extended families, many of whom have had similar negative experiences in schools, have consequently had limited involvement in the education process, and almost no involvement in science and mathematics. All of this has contributed to teacher expectations that have been less than positive with regard to the success of these students in science and mathematics classrooms. This lack of support from parents, communities, and educational systems makes it unfeasible for most Hispanics and American Indians to even consider pursuing further education and careers in science and mathematics.

We recommend that teachers develop a knowledge base about the various cultures (including languages) of their students, and incorporate this cultural knowledge into their teaching strategies and curriculum. It is essential for teachers to understand the cultural traditions of their students, especially in areas that may cause students to have restricted positive experiences in science and mathematics. It is also important for teachers to have an appreciation of the learning styles and strengths of their students, particularly those whose backgrounds differ from the mainstream. In light of this, teachers should closely monitor their own spoken and unspoken expectations of Hispanic and American Indian students with regard to success in science and mathematics, and they should extend their own education and understandings so that they may meet the needs of and encourage all students in traditional fields of study.

In addition to the role of the teacher and school in increasing success of these students in science and mathematics, the parents and the community need to be invited to participate in K-12 science and mathematics curriculum, events and studies. This enriched curriculum will then be reflective of the students' experiences, culture and language, and the corresponding assessment practices will be appropriately linked to contexts within the culture providing a greater potential for successfully revealing what students do not know.

Science and mathematics teacher educators have an important role in this whole process in that they must be knowledgeable about the various cultures that make up American society, and must incorporate and model multicultural education strategies into their own teaching. To accomplish this, they should be at the forefront and be familiar with the research on multicultural science and mathematics education so that they can effectively teach preservice and inservice teachers how to infuse cultural knowledge and practices into K-12 science and mathematics instruction.

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WOMEN, WIFE, MOMMY, AND SCIENTIST: HELPING FEMALES SEE THEMSELVES IN SCIENCE

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Purpose of the Study

The purpose of this study was to determine the enabling and potentially disabling factors in the lives of contemporary women scientists, factors which either facilitated their goals of being scientists or which had the potential to obstruct their paths toward their goals. This study was an examination of the lives of women scientists from their early memories to their lives at the conclusion of the study in 1996. The women scientists in the study were encouraged to explore their own lives for factors which enabled them to become scientists and for factors which enabled them to maintain their credibility in their careers. Also examined were the social factors important in their lives, including friendships, family interactions, romances, marriage, and motherhood. The factors which contributed to the participants' achievements were characterized as enabling factors.

In addition to enabling factors, the participants in the study revealed factors in their lives which had the potential to prevent their pursuit of science studies, or to cause detours from intended study and career. Since other young women who lacked an array of enabling factors could be dissuaded by the disabling factors, it was important to consider not only what brought the participants of this study to their science, but also what could have kept them from their calling.

Through understanding both enabling and potentially disabling factors in the participants' lives, college science educators and K-12 teachers will have a more complete understanding of the dilemmas females face when deciding whether or not to take higher level science courses and consider a science major. Parents and educators can anticipate the needs and concerns of talented young women. Also, premises against which the credibility of scientists are judged can be re-examined to ensure that talented women in the sciences who are also wives and mothers have opportunity and support for their work in science.

Conceptual Framework

The problem of attracting women into science courses and into pursuing science careers has been the focus of many studies (Koballa, 1988; Kahle, 1990; American Association of University Women, 1992; Erickson & Erickson, 1994). In his pivotal essay on the need for including various aspects of society in the scientific dialogue, *The Two Cultures* (1962), C. P. Snow emphasized the deficit in potential knowledge suffered by the scientific community due to the virtual exclusion of females from the ranks of scientific academics. In a study of intended majors of college freshman, Vetter (1987) found that 14% of the female freshmen intended to major in a science area, contrasted with 40% of the males. As they got nearer to the conclusion of their education, the proportion of women who dropped science majors increased (Berryman, 1983; Matyas, 1986). Dresselhaus, Franz, & Clark (1994) reported that the proportion of women to men in science faculty positions in the United States was much lower than the proportion of women to men in undergraduate and graduate science degree programs. Thus, despite modestly successful efforts to bring women into the sciences during the past several decades, a deficit still existed in the scientific community.

If women were to be included in the scientific community in a meaningful way, it was not enough to determine how to persuade girls to aspire to science careers and to take higher level science classes in high school. Attention must also be given to the processes at play in undergraduate and graduate studies, as well as in the transition between student and practicing scientist. In addition, a broader understanding of the processes was needed, one which went beyond academic preparation to the social influences (Kahle, 1990). In a ten-year study of high school valedictorians, Arnold (1993) found that females were twice as likely as males to be married at the end of the ten years, and the females who were not married expected to experience conflict between work and family goals should they marry. Of the women physicists in the Arnold study, most, in retrospect, felt ambivalent about their career choice, and all predicted they would cut back on work at some point for childrearing. It could be concluded from the Arnold study that it was improbable that a person could be a woman, with the contingent roles of wife and mother, and be a scientist.

Methodology

In this study, an emergent design was utilized of the type described by Lincoln and Guba (1985), involving field observations and individual semi-structured interviews. Two tape-recorded interviews were conducted with each participant. The first interview involved general questions and responses, and the second interview was structured through focused questions derived from examination of the first interviews and the development of coding schemes from the information obtained in those first interviews. The strategy for development of the coding schemes was a variation of the cross-case analysis/inductive approach described by Glaser and Strauss (1967). The second interviews were conducted a year following the first interviews, and all interviews were conducted within the same two-year time period. Case studies were developed for each individual interviewed, and a cross-case analysis was developed. From these case studies and the cross-case analysis, conclusions were derived about the enabling and disabling factors for these women in becoming scientists and in maintaining credibility as scientists.

Trustworthiness of the results and conclusions of this study was established through the use of member (participant) checking of transcripts, case studies and analyses, and of conclusions. An external auditor certified the data acquisition and coding process. A peer reviewer examined the study documents for consistency of data with results and conclusions.

The participants in this study were six women scientists from various science disciplines: a meteorologist, a forensic pathologist, a geologist, a physicist/astronaut, and two astronomers. Selection of participants was accomplished through discussion with scientific professionals and the solicitation of their recommendations as to who would be valuable participants in this study. Ages of the participants at the conclusion of the study ranged from 32 to 67 years old. The meteorologist was the first woman Senior Scientist at a major atmospheric research facility. The forensic pathologist is Chief Medical Examiner for her state. The geologist is in a tenure-track position at her university, and has recently returned from a year of maternity leave to full-time teaching and research in volcanic/tectonic geology. The physicist/astronaut flew on four Space Shuttle missions, experienced several spacewalks and served as Mission Commander in charge of the anti-gravity research on her last mission. One of the astronomers is a recipient of the Presidential Medal of Freedom and a member of the National Academy of Science. The other astronomer is the first female to be awarded a tenured position in her university's astronomy department. Participants granted permission for use of their information in the study. Specific identities are confidential and pseudonyms are used.

Nature of the Data

The data of this study consisted of information from the two interviews with the participants and from observations of the researcher as recorded in field notes. The results were derived from case studies which were developed from information from the interview transcripts and from the observations of the researcher. An abbreviated passage from each case study follows.

Meteorologist: Libby

Childhood

Third grade show and tell was especially exciting that day for the little girl in the second row. It was Tuesday, her row's turn, and she had something for show and tell that had never been seen in her midwest elementary classroom. Libby's house had been struck by lightning the night before, and she had brought in bricks knocked from the chimney and pieces of woven plastic from where the bricks had hit the lawn furniture and shredded the seats and backs. Before lightning struck her house Libby had wanted to be a fireman, but this event changed her mind. Now, she wanted to study weather.

Forensic Scientist and Chief Medical Examiner: Sophy

Childhood

Sophy's father died when Sophy was 13, leaving Sophy's mother to raise Sophy and her nine-year-old sister. This did not prevent Sophy from being involved with outside activities. Her mother had managed the finances for the family even before her father's death, and afterwards

Sophy and her mother took primary responsibility for household repairs. There was barely enough money for essentials, much less to pay others for repairs and maintenance of the home. Sophy recalled the repair of a concrete wall in the basement, when she and her mother took out all the crumbling mortar and replaced it. Few household repairs were beyond their capabilities, and Sophy learned to wield a paintbrush, hammer, chisel, shovel, and rake with finesse.

Geologist: Sue

Profession, Marriage, and Motherhood

At the time of the first interview, Sue had been married less than a year. When she was asked what she saw herself doing in the next five years, Sue immediately replied, "I'd like to have a child." She was unsure about the changes having a child would bring, including the risk to getting tenure, yet she was almost 34 years old and her husband was 50. "We're married now, and want to have a baby now!" Patricia was born in the late summer of the following year. Six months later the second interview took place in the charmingly chaotic setting commonly found in the living rooms of homes with babies.

Astronaut/Physicist: Carol

Profession, Marriage, and Motherhood

Carol applied to the NASA astronaut program, and was notified of her acceptance in 1984. She became an astronaut in 1985, and five months later gave birth to her second daughter. By this time she was living near the NASA space center where astronauts underwent their training, and her husband remained at their home hundreds of miles away. Though functioning for the most part as a single mother, she did not anguish over her responsibilities with her children.

> You choose what you do with those twenty-four hours in a day . . . You just concentrate on what's important in each of these areas, and let everything else go. I take care of my kids as best I can. I'm not always there for them, but they're pretty independent little kids right now, probably because of that. I wouldn't win the Good Housekeeping Award, but it's sanitary and livable [at my house], and that's good enough for us.

Astronomer: Florence

Profession and Motherhood

While reflecting upon motherhood, Florence discussed the reason she thought it was important for her to do her science:

> Having children was in no way antagonistic to being a scientist. You have to have a life. You either have to scrub your floor or go to the telescope, and I'd much rather go to the telescope than scrub the floor . . . . We ALL work, whether we're doing something ennobling and elegant or something horrible . . . . So, just having the children, having them around, was never a problem for the science.

Among the aspects of science that Florence found distasteful, and which she had avoided was the "very rough level" of competition she had encountered. Florence wanted to do things at her own pace. She confessed she had even avoided some research because it was too popular, implying that she didn't want the popularity of the topic to cause her to feel pressure to rush her work or tailor her work to avoid someone else's topic. "I didn't like the intense scientific competition . . . I didn't like being attacked." Florence hoped that her own conscious decision to resist that aspect of science research would contribute, along with other women's efforts, to changing the way things were done.

Astronomer: Maria

College

Though most doctoral students spend three or four years completing their work and getting their degree, Maria was seven years at the university. Maria remembered that the attitude of the faculty was rather distant and she did not feel the faculty were interested in students as individuals. There was a sense of competition, with students ranked by the faculty for preference in funding for professional conference attendance and other special considerations. Competitive pressure was compounded by the knowledge that there were plenty of applicants to replace Maria and the other students if they did not meet the doctoral standards. However, there was no explaining the unfair grading practices, where Maria and a classmate would have virtually the same answer and "I'd get

50% and the other, you know, the guy, would get 100% for the question." When she checked around, Maria discovered the women in the class were the ones getting the low grades. She was consistently told by an advisor that she needed to "do more," and when she did more it still was not enough. Her major advisors were remembered as unkind, unappreciative, unsupportive, and even obstructive. After seven years, Maria threatened her doctoral thesis advisor - she was embarrassed to admit she even swore at him. If he didn't set her dissertation defense within 24 hours, she was going to the chairman of the department and telling him she was quitting graduate school. She didn't care anymore about becoming an astronomer; she just wanted to get out of that university.

Results

The primary enabling factor in the lives of these women was a determination to become a scientist. Markus and Nurius (1986) named the expectation of reaching such a goal as the sense of "possible self." These women had a pronounced sense of possible-self-as-a-scientist. Certain consistent supporting elements preserved this sense of possible self: a supportive home situation and the contribution of parents. Other factors which were important included strong maternal role models, expectation of financial responsibility, support of husbands, availability of spousal employment, childhood opportunity to participate in activities outside the school setting, and single-sex schools.

Potentially disabling factors included sexist aspects of K-12 and graduate schools, of professional life in science, paternalism of institutions, living apart from husbands, teacher attitudes, and extreme competitiveness. This competitiveness was manifested in discussion styles both in class and informally, and in social and assessment situations. In many circumstances there was a contrast between the treatment of male students and female students. Women experienced situations where major professors took longer to approve their work than similar work submitted by male students, and the professors required more revisions. In one event, an innocent mentor/mentee relationship was marred by academic society gossip. Lack of confidence in one's own abilities, a factor spotlighted in DeBoer's study in 1986, was a component in an array of insecurities experienced by one of the women. Several of the women recalled discomfort at the low number of women colleagues they had around them during their graduate studies.

All the women had husbands who were academics or scientific professionals, and none of the women have ever been divorced. All had children. Neither marital nor maternity status of the participants had been a stated quality for selection as a participant in this study, yet all participants were married, in apparently stable relationships, and were mothers.

Conclusions

The underlying importance of parental support is paramount. Though schools may want to shoulder the responsibility for encouraging young women in science, it must be recognized that parents are necessary partners in the enterprise. Family considerations and an emphasis on relationships were also crucial to the perseverance of these women. A component of this study of women scientists was their emphasis on the importance of the support of their husbands, and of other male mentors and friends. The fact that all these women were still married to their first husbands, or were widows who remarried, indicated a commitment to being wives as well as scientists. By the end of the study all the families had children, which again indicated a commitment to a feminine role while fulfilling the role of woman scientist.

Science educators have a responsibility to encourage girls in their classes and in informal interactions. These professionals also have a responsibility to inform and counsel others who are influential in the development of students. Recommendations to science educators for encouraging females in science include:

1. Advise parents about ways to enable their daughters. Inform parents of the importance of manipulative play and the freedom to explore, and of the benefits of teaching their daughters how to do some traditionally male tasks, such as fixing machinery. Inform parents of the importance and nature of effective parental support, especially in the form of rejection of

traditional role assumptions. The women in this study were not told they couldn't do things because they were female.

2. Inform parents, other teachers, and guidance counselors of the benefit of establishing in girls expectations of financial independence. Communicate information about the range of options available for financing the education of aspiring female scientists from a wide range of family incomes.
3. Implement equity curricula in schools.
4. Encourage girls to participate in organizations that develop their manipulative skills, such as Girl Scouts, Campfire Girls, and 4-H clubs.
5. Provide experiences for girls, in and out of school, so that they have opportunity, time, and materials for working through an activity in order for manipulative skills, proportional reasoning, spatial awareness, and self-confidence to be facilitated.
6. Encourage single-sex schools for the purpose of developing a sense of possible-self-as-scientist. Inform parents and school system personnel of the benefits of single-sex schools as revealed in the stories of these six women scientists. While attending a single-sex school, encourage girls to develop qualities of leadership, academic excellence, and to recognize these qualities in themselves. If single-sex schools are not available, provide single-sex classes in physics and chemistry. Encourage girls to take advantage of such options. If those options are not available, girls should be encouraged to take physics and chemistry classes regardless of the number of other girls taking the class.
7. Encourage behaviors in female friends which support the development of self-confidence in others. These behaviors include a regard for intellectual achievement and also of feminine characteristics cited in this study, such as an appreciation of cooperative as well as competitive abilities.
8. Inform the faculties of colleges and universities of the stories of these women and of their expressions of the importance of having women students and faculty in the sciences to serve as a community of females within which women can identify.

9. Inform teachers, parents, and guidance counselors of the importance of relationships with family and friends to a girl's sense of identity.

10. Encourage boys to support the development of self-confidence in their female friends, and inform boys of the positive role that male friends played in the lives of the participants in this study.

12. Inform girls of the potential benefits of developing supportive friendships with boys.

13. Advise teachers of the impact of extreme competitiveness and pressure upon students, and of the potential loss of talented scientists when such competitiveness is emphasized.

Most importantly, science educators should examine their own practices and critically assess and adapt their attitudes and behaviors related to females. Cultural pressures are pervasive and insidious, and, as such, influence us all. If science educators are to advise others, they must first look to themselves.

Significance

Despite various potentially disabling situations where others in academic situations attempted to drive home the message of female inferiority, these women had sufficient self confidence and sense of possible self to outweigh the sexism encountered. They succeeded, yet their reflections upon their success revealed probable reasons why so many others did not and do not succeed.

The long-term goal of this study, to determine factors which enable women in the sciences, was chosen in hope of finding avenues for opening doors for more women in the sciences, women who may not be so determined and assured. The fact that these six women are so competent and valuable to science makes the sexism they encountered especially appalling. Often, it was implicit and well-meaning, yet thoughtless. An aspect of implicit sexism not often recognized is the lack of women in the field, and how that discourages other women from entering the field.

Explicit sexism was undeniable in some of the stories. Stories remembered by Florence and Sophy, who received their training in the 1950's and 1960's, are replete with denial of opportunity and with venomous intent. Considering these cases, it might seem that explicit sexism was an artifact of the recent past. However, Libby, Maria, and Sue told of difficulties connected to explicit sexism in high school, undergraduate, and graduate school, as well as in their professional experiences. Recognition of the contributions of the six women to science came reluctantly from many of the men in their professional spheres, as though the men could only see value in thought which was an extension of their tradition. The lives of these six women refuted the assumption among most young females that pursuing science careers would mean giving up or greatly altering the feminine roles of wife and mother. Though they expressed many frustrations about situations encountered in the pursuit of their credentials, and about circumstances which presented challenges as they functioned as mothers, wives, and women scientists, they were confident in their own futures. They revealed that there is a place for women in the sciences that is compatible with femininity. The term "woman scientist" is not an oxymoron.

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VOLITIONAL CHANGE IN ELEMENTARY TEACHERS' CONCEPTIONS OF SCIENCE PEDAGOGY VIA A GENERATIVE LEARNING MODEL OF TEACHING

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A Study of Change

Past studies in science education have examined the problem of changing children's conceptions about scientific ideas and theories. However, such studies have routinely centered on the conceptual changes in the learner's thinking about science, not change in the teacher's conceptions of pedagogy as it relates to the meaningful teaching and learning of science in the elementary school.

"Change is a process of coming to grips with new personal meaning, and so it is a learning process" (Fullan & Miles, 1995, p. 408). The personal meaning of change for teachers is intrinsic to successful reform and change in science education. Introducing the methodology of the Generative Learning Model (GLM) of teaching (Osborne & Freyberg, 1985) to the participants in this study provided the means for the teachers to experience new meaning and new learning about science pedagogy.

The organizational structure created by American education often neglects the needs of teachers as adult learners. In the past, educational reformers looked at inservice programs and workshops as vehicles to fix what they perceived to be wrong with teachers and schools. This mindset produces teachers who never gain control of any area of practice where they are in charge or are viewed as experts (Lortie, 1975). When principals, superintendents, and school administrators are presumed to be persons of greater expertise and standing, daily teaching operations and pedagogy are dominated by persons in other roles, not by the teachers themselves. Without ownership of the ideas presented in the program or workshop, teachers are unlikely to fully adopt the ideas into their practices.

Professional development is still under scrutiny by curriculum reformers. The traditional approach of using teacher development and inservice programs as a setting to "fix" schools is still in practice. Connelly and Clandinin (1988) find remnants of the teacher-proofing idea in government policy documents of centralized countries worldwide. These curricular materials minimize teacher influence and were developed to treat the existing school problems. Connelly and Clandinin (1988) ask workshop presenters and participants a soul-searching question.

> If workshops train teachers to teach in certain ways, how is this any different, in principle, from bypassing teachers altogether in teacher proofing of curriculum materials? There are, of course, many excellent professional development and teacher workshops. We want teachers to be able to judge for themselves whether the professional activities in which they engage are educational or whether they are designed as an alternative to teacher proofing. It is your professional development. You must judge. (p. 139)

As science educators reexamine the purpose and the goals of teacher workshops and inservice programs, the emphasis again falls on the teachers themselves. The understanding of the pivotal role of teachers in the process of change and innovation in science education is of the utmost importance.

Teachers as Adult Learners

Adult learning theorists (Knowles 1984; Mezirow, 1989) believe that adults become increasingly self-directed and that their readiness to learn is stimulated by real life tasks and problems. Mezirow (1990) proposes that learning takes place through the analysis of problems and the generation of themes that are the content of a learning situation. Mezirow's theory of perspective transformation deals directly with learning through the process of critical reflection. The critical reflection results in transformative learning through the insights of self-reflection and the realization of how perceptions can be changed to allow new possibilities for meaning.

To make meaning the adult makes sense of an experience and then interprets the experience to guide his or her actions. Distortions in beliefs and errors in problem solving are then corrected by reflection, a synonym for higher-order mental processes in this theory. But the critical reflection, concerned with the why and the reasons for consequences, is not part of the immediate action process. A hiatus, an anomaly, or a dilemma that challenges or disorients the learner's current way of knowing initiates the transformation. The impetus for perspective transformation mimics the conditions for a theory of conceptual change (Piaget, 1963; Posner, Strike, Hewson, & Getzog, 1982) when dissatisfaction with current understandings exists and the learner begins to look for a plausible alternative.

Conceptual Learning

Since the late 1970s Posner, et al. (1982) asked teachers to facilitate the learner's accommodation of new conceptions in science through a theory of conceptual change. Inquiry, children's questions, the science process skills, and discrepant events are integral parts of science instruction used by teachers to promote conceptual change. The slowly evolving process of conceptual change requires time to test ideas and to manipulate materials during experimentation. After the learner confronts errors in understanding, a new concept replaces the old concept through the process of reflective thinking about observations and findings from tests and experiments.

> Learners bring their idiosyncratic and personal experiences to most learning situations. These experiences have a profound effect on the learners' views of the world and a startling effect on their willingness and ability to accept other, more scientifically grounded explanations of how the world works. Teachers who take a personal, adaptive view of knowledge are known as *constructivists* because their model of learning posits that all knowledge is constructed by the individual in a scheme of accommodation and assimilation. (Watson & Konicek, 1990, p. 682)

Generative Learning

Osborne and Wittrock (1983) describe learning science as a generative process of constructing meaning from one's own memories, knowledge, and experiences, and from incoming sensory information. When a learner does something with that information, "that something is the generation, the active relating of the pupil's knowledge, logic, and experiences to parts of the statement or explanation, and the construction of meaning." (p. 499). Osborne and Freyberg (1985) describe a teaching model that "requires active teaching by a teacher who clearly appreciates children's ideas, the scientific view to be encouraged, the types of activities that might achieve conceptual change, and the associated interactive teaching sequences which need to be adopted" (p. 111).

The Generative Learning Model encompasses a four phase teaching sequence that includes the preliminary, focus, challenge, and application phases. Cosgrove and Osborne (1985) propose this model for three specific objectives: "clarification of the pupil's existing views, modification of these views towards the current scientific view, and consolidation of the scientific view within the background and values of the pupils." (p. 107).

The view held by Osborne and Freyberg (1985) and those utilizing the GLM recognizes that new ideas can be constructed only through sensory input by using existing ideas in memory store. Practicing teachers have their own interpretations of the experience of teaching science. An innovation, the GLM, prompts teachers to reflect about current practices and empowers them to reconsider their conceptions about teaching and learning in science.

The GLM is a particularly effective model used to identify and address student misconceptions about scientific phenomena. In the Preliminary Phase, the teacher applies a variety of methods to assess student preconceptions. Once the conceptions are identified, the teacher centers on interaction, both with physical phenomena and with peers, to aid learners in their restructuring of concepts during the Focus Phase. Mestre and Touger (1989) suggest that teachers should continually watch and carefully listen for conceptions that may emerge by allowing students ample opportunities to explain concepts in their own words in an atmosphere that is sensitive and receptive to their views. They add that "simply telling students that their conceptual understanding is wrong or incomplete, and combining this with a correct explanation, is often not sufficient for eradicating most misconceptions" (p. 450). During the Challenge Phase, the teacher facilitates the exchange of views, keeps discussion open, and presents the scientist's view of the concepts in the lesson. Finally, during the Application Phase, the teacher contrives problems, assists students in clarifying the new view, and ensures that pupils can describe solutions to problems.

Workshops: An Introduction to Innovation

Workshops are a means used to introduce an innovation or a new idea in science teaching. The presentation of the ideas for dissemination is an important foundation for change and reform in science education. In the analysis of the elements of innovation or a new approach Rogers (1962) lists four crucial components for the dissemination of ideas: (a) The innovation is an idea perceived as new by the individual; (b) Communication is the diffusion process in which one person communicates a new idea to another person; (c) The social system is the population of individuals who are cooperating to solve a common problem; (d) Adoption is the decision to continue full use of an innovation. Rogers' ideas about crucial components for the dissemination of ideas apply to teachers and their opportunities for appraisal and adoption of innovation. The teacher workshop itself is an environment where communication takes place and diffusion of an innovation begins.

The constructivist orientation in the design of professional development for teachers of science emphasizes the importance of personal cognition and social collegiality in the learning process (Brown & Sinclair, 1993). Gore (1991) recommends program-specific workshops conducted by the university to provide a context for sharing and forming a more common knowledge base.

> Teacher learning is often not valued to the extent that teachers are provided with time to work with their peers, to reflect systematically on their teaching, to attend workshops to strengthen what they bring to their teaching or their involvement in student teaching. (Gore, 1991, p. 265)

The constructivist view does not consider it possible for workshop presenters to transfer new ideas from the presenter to the participants by imparting instructions about curricular materials. The presenter actively engages the participants in hands-on/minds-on activities to improve the teachers' abilities to engage students in scientific inquiry. The constructivist presenter offers opportunities for teachers to explore learning in inquiry-oriented situations, to share ideas across grade levels, and to integrate science with other disciplines. Instructional strategies congruent with the constructivist epistemology include (a) the use of the science process skills by using data-gathering and data-processing components, (b) cooperative-group techniques, (c) productive questioning skills, and (d) discrepant events as a motivating technique are modeled during the workshop program.

GLM Workshops in the Study of Change

The researcher was the presenter for the staff development workshops held during the study. The GLM of teaching was introduced as an innovation at the workshops. An orientation to the constructivist perspective was achieved during the workshops through activities designed to build community spirit, research-based explanations describing the constructivist epistemology, and instructions about the conditions for conceptual change. The teachers participated in science activities exemplifying the phases of the GLM of teaching. Also, a guest at the first workshop presented video cases of teachers using the GLM in classroom settings. A laser disk program (Abell, Campbell, & Cennamo, 1994) further exemplified the model's implementation. The participants shared ideas about science teaching and about the implementation of the GLM in the classroom at the second and third workshops. The researcher continued to model lessons and to exhibit the phases of the GLM. Peer teaching was also used to share examples of lessons implementing the GLM.

The teachers in this study attended three staff development workshops centered on the innovation, the GLM of teaching. The conceptual change approach of the GLM represented new meaning and new learning in science education for the participants in the study. The GLM was an inducement for thinking about personal conceptual change in science pedagogy. The teachers experienced the model and then applied the concepts and ideas learned to the construction of personal knowledge about classroom practice. At the beginning of the study, each individual teacher approached a change in pedagogy from his or her own perspective. As the study progressed, the participants became a community of learners supporting each other during the project. The individual participants made sense of their personal meaning of the innovation and then they shared their thinking and reflections to sustain the conditions for change during group discussions.

Purpose of the Study

The purpose of this study was to document and analyze the changes in the meanings, thoughts, and beliefs of practicing elementary school teachers about science pedagogy via a GLM of Teaching. The researcher and eight practicing teachers (co-researchers) engaged in heuristic research to explore adult learning and to reveal changes in teacher thinking about teaching and learning science in the elementary classroom.

Research Methodology

Since the 1960s and 1970s a different approach to research on teaching has emerged (Erickson, 1986). The social sciences used this approach for about seventy years previous to these decades. Erickson refers to the whole family of approaches to participant observational research as interpretive. Interpretive research can lead the researcher to search for the nature of environments, reflection, and meaning-perspectives. Issues, problems, and projects, especially in educational research, can use interpretation to define phenomena of interest.

Heuristics, a form of phenomenological methodology, is concerned with meanings, essence, quality, and experience. A quantitative approach, in contrast, is concerned with measurements, appearances, quantity, and behavior. Heuristic research "epitomizes the phenomenological emphasis on meanings and knowing through personal experience; it exemplifies and places at the fore the way in which the researcher is the primary instrument in qualitative inquiry; and it challenges in the extreme traditional scientific concerns about researcher objectivity and detachment" (Patton, 1990, p. 73). In heuristic analysis, the insights and experiences of the analyst are primary to the creative synthesis of the total experience.

The self of the researcher is present throughout the process, while understanding the phenomenon with increasing depth, the researcher also experiences growing

> self-awarenesses and self-knowledge. Heuristic processes incorporate creative self-processes and self-discoveries. (Moustakas, 1990, p. 9)

Heuristic research "refers to a process of internal search through which one discovers the nature and meaning of experience and develops methods and procedures for further investigation and analysis" (Moustakas, 1990, p. 9).

Theoretical Framework: Heuristic Inquiry

Heuristic inquiry, a form of phenomenology, asks the researcher to make meaning about the experiences of the phenomenon studied (Patton, 1990). The researcher's personal experiences and insights into a chosen phenomenon of intense interest require a theoretical framework beyond a purely phenomenological approach. The researcher's experiences with the phenomenon studied coupled with an intense point of view about the phenomenon, enable the researcher to develop and understand the essence of the meaning of the phenomenon.

As the participants experience and reflect about the phenomenon studied, they, along with the principal researcher, come to understand the essence of the meaning of the phenomenon. The participants in the study become co-researchers (Patton, 1990). As the principal researcher and the co-researchers mutually strive to make meaning about the nature and the essence of their human experiences, they develop a connectedness through shared reflection and inquiry.

Polanyi and Prosch (1975) describe the effects of human thought in heuristic terms.

> When one sees a problem and undertakes its pursuit, one sees a range of potentialities for meaning which one thinks are accessible. Heuristic tension in a mind seems therefore to be generated much as kinetic energy in physics is generated by the accessibility of stabler configurations. The tension in a mind, however, seems by contrast to be deliberate. (p. 176)

An interpretive study asking participants to analyze thoughts, meanings, and beliefs can best be characterized in Polanyi's (1958) terms as a heuristic act. He describes the adaptation of a framework to fit new experiences and the discovery of movement from one framework to another as heuristic vision.

The heuristic act of achieving innovation is not a routine application of new knowledge, but it is an act of invention and discovery. Polanyi talks about personal revisions of guiding assumptions that change the rules for interpreting our experiences. Challenging the rules and assumptions about teaching science may encourage a breakout from an established framework. Clandinin (1986) interprets Polanyi's descriptions of heuristic acts as "acts achieving innovation . . . . It relies on personal intervention for changing the rules" (p. 28).

Moustakas (1990) defines heuristic inquiry as "a process that begins with a question or problem which the researcher seeks to illuminate or answer. The question is one that has been a personal challenge and puzzlement in the search to understand one's self and the world in which one lives" (p. 15). Self-dialogue and self-discovery guided my requests for disclosure from the teachers in the study about their thoughts and beliefs. Our work together reveals the meanings and essences of teacher thinking about science pedagogy.

Data Collection

The theoretical framework of heuristic inquiry, a form of phenomenology, and a constructivist epistemology entwined to form a conceptual framework for the interpretation and analysis of the data collected about conceptual change in teacher thinking about teaching and learning in science. This qualitative study utilizing ethnographic methods (field notes, artifacts analysis, focus group discussions, and interviews) enabled the researcher to discover the essence of the conceptual change experiences of the individual participants. The descriptive data from interviews, focus group discussions, and personal journals depicted the lived experiences of the practicing teachers and were interpreted from the perspective of the investigator.

The methodology of heuristic research enabled the researcher to generate an interpretation for the essence of the conceptual change experience of the individual participants in the study. "In heuristics, an unshakable connection exists between what is out there, in its appearance and reality, and what is within me in reflective thought, feeling, and awareness" (Moustakas, 1990, p. 12). This heuristic work was created from my self-search and self-dialogue relating to appropriate pedagogy for the teaching and learning of elementary school science and was united with the reflections of the participants in the study to interpret volitional changes in our collective thinking about the practice of conceptual change teaching.

Research Questions

Moustakas (1990) describes the formulation of the research question in this way. "All heuristic inquiry begins with the internal search to discover with an encompassing puzzlement, a passionate desire to know, a devotion and commitment to pursue a question that is strongly connected to one's own identity and selfhood" (p. 40).

The original, overarching research question gets the researcher started and helps the researcher stay focused throughout the research project. The overarching question for this study was:

- What are the changes in the meanings, thoughts, and beliefs of elementary school science teachers about science pedagogy via a Generative Learning Model of teaching?

The research questions define how the data is collected and analyzed. They also describe relationships sought, facts discovered, or concepts generated (LeCompte & Preissle, 1993). Related questions seek to identify and to clarify the research purpose. Related research questions were:

- In what ways do elementary teachers change their conceptions about how to teach science?
- Does a conceptual change in the elementary teachers' ideas about science teaching precede the ability to affect conceptual change in students' ideas about science?
- Can elementary science teachers apply their reflections about conceptual conflict to pedagogical practices in the classroom?

A methodology stemming from a qualitative tradition was selected to interpret the thoughts, meanings, and beliefs of the participants in the study. The interpretive research sought to investigate the invisibility of teachers' thoughts and to document their meanings (Erickson, 1986) for the details of change in the practice of teaching science. The theoretical framework of heuristic inquiry (Moustakas, 1990) and the epistemology of constructivism (Bartlett, 1932; Piaget, 1963;

Vygotsky, 1978; Bruner, 1986; & Fosnot, 1989) guided the collection and the analysis of the data. Heuristic inquiry and constructivism formed the conceptual framework through which the assertions were generated. The yearlong study included three phases of research (see Table 1).

Table 1
Phases of the Research Project

PHASE	RESEARCHER AND CO-RESEARCHER ACTIONS
One	Ascertain teachers' thoughts, meanings, and beliefs about science pedagogy during the initial, one-on-one interviews.
Two	Introduce and model the innovation, the GLM, at three staff development workshops. Provide time and space for individual reflection via journal keeping and for collegial interaction via focus group discussions.
Three	Disclose volitional changes in teachers' conceptions of science pedagogy during final interviews.

Participants

The eight practicing teachers in the study exemplified a wide range of characteristics and attributes. Pseudonyms were chosen to protect privacy and confidentiality. There were seven females and one male in the group of participating teachers. Table 2 presents data about the participants.

Table 2
Participants

NAME	YEARS OF TEACHING	GRADE LEVEL	DEGREE (GRADUATE)
Sharon	18.5	3	M. Equiv.
Chris	5	4	M. SciEd
Ian	14	2	N/A
Eileen	28	3	M. Ed
Nancy	20	2	M. Ed
Cathy	14.5	3	N/A
Elizabeth	19	6	M. SciEd
Susan	29	2	N/A

Two sites were selected for the study by accessibility and by convenience. Both sites were elementary schools in northwestern Pennsylvania. The superintendents of the sites gave permission for participation of the teachers in the districts and the principals of the elementary schools arranged for a presentation about the project at a faculty meeting. The proposed strategy for this study was to include all volunteers who agreed to participate. Four teachers volunteered from one site and five teachers volunteered from the second site. All were selected to participate. Shortly after the study began one of the teachers broke her leg and could not continue.

Three workshops were designed and developed to introduce, present, and involve the participants in experiences with the GLM of teaching. The setting for the workshops and the format of the presentation for the workshops were critical to the development of the desired classroom environment for the teaching of science. The site for the workshops was a central location for the teachers from both school districts. The director of a state-funded science teacher education program offered the use of the program's facilities. A classroom with comfortable chairs, an office staff that was helpful and attentive to our needs, and a library of curricular materials made this site a nonthreatening, relaxed, and accommodating environment for the presentation of the workshops. The workshops were held on three school days about once a month over a three month period.

Funding for the substitute teachers on the days the workshops were held was accepted from a variety of sources. One of the superintendents offered to fund the substitute teachers from his school district for one workshop. The director of the state science teacher education program funded substitute teachers for two workshops and the researcher funded the substitute teachers from one district for one workshop. An honorarium was offered to the presenter who attended Workshop One by the state science teacher education program. Lunch was provided by the researcher on all three workshop days.

Technique of Analysis

The qualitative methods in this study consisted of three kinds of data collection: (a) in-depth, one-on-one, open-ended interviews, (b) focus group discussions, and (c) written documents. Through the use of multiple methods of data collection including interviews, observations during workshop sessions, and document analyses, a mix of components were available for triangulation. LeCompte and Preissle (1993) describe triangulation as the means the ethnographer uses to pinpoint the accuracy of conclusions drawn during data analysis. Triangulation prevents the researcher from accepting initial impressions too readily. Miles and Huberman (1984) describe triangulation as a state of mind. "If you *self-consciously* set out to collect and double-check findings, using multiple sources and modes of evidence, the verification process will largely be built into the data-gathering process, and little more need be done than to report on one's procedures" (p. 235).

Moustakas (1990) suggests that a typical way of gathering material in a heuristic investigation is "through extended interviews that often take the form of dialogues with oneself and one's research participants" (p. 46). The dialogues in this study involved cooperative sharing, comprehensive conversations, and open honesty. In-depth interviews involved personal, interactive conversations with the participants. The interviews were held at the convenience of the teachers, usually before or after school, and were audio taped and transcribed.

The initial interviews for the participants were held at the beginning of the school year at the respective school sites. The researcher inquired about the teachers' lives inside and apart from school and about their educational backgrounds. The researcher asked each teacher to describe his or her beliefs, methodologies, and experiences as an elementary teacher of science. The interviews were intended to be open, flexible, and empathetic. The final interviews were conducted at the end of the school year at the school sites. The teachers described their conceptions about science pedagogy after the yearlong research project. The responses about their thinking and actions connected to the GLM were rich, vivid, and extensive.

Focus group discussions were held at two of the teacher workshops. Bers (1989) defines a focus group as "a small (6-12 member), relatively homogeneous group that meets with a trained moderator who facilitates a 90-to 120-minute discussion in a nonthreatening, relaxed environment about a selected topic" (p. 261). The discussions generated interactions among the teachers eliciting the rich, deep data inherent in the synergy of small groups. The output from the discussions provided a voice for the participants.

New thought was stimulated in part because of the safety in "groups of like kind" (Lederman, 1990, p. 120). The homogeneity of the group along with the vis-à-vis context generated ideas, provided feedback, and awakened conversations. The focus group discussions were about one and a half hours in length. The discussions were tape-recorded and transcribed.

Additional meaning and depth to supplement the co-researchers' depictions were obtained in the form of personal documents. The participants constructed personal diaries at the first teacher workshop. The teachers wrote in the personal, reflective journals throughout the school year. The entries offered additional meanings of their experiences and thoughts. The researcher also wrote field notes in her personal journal during the focus group discussions and during the peer teaching experiences. (See Table 3.)

Table 3
Time Line for the Study of Change

SEPT	9/14 & 9/23	9/28
1994	Written permission to proceed from superintendents	Attendance at faculty meeting to invite volunteer participation
OCT 1994	10/10 Written permission from Research Coordinator for Regulatory Compliance to proceed	10/14 Attendance at faculty meeting at second site to recruit volunteers
	10/28 Approval from doctoral committee to begin	10/31 Initial interviews begin Study begins
NOV 1994	Initial interviews continue	
DEC 1994	Initial interviews end	
JAN 1995	1/6 First teacher workshop 9 - 3	Introduce the GLM Laser Disk presentation Begin journals
MAR 1995	3/3 Second teacher workshop 9 - 3	Focus group discussion about GLM in practice
	3/31 Third teacher workshop 9 - 3	Focus group discussion about GLM in practice Peer teaching and sharing
APRIL	4/12 Final interviews begin	
MAY	5/8 Final interviews end, collect journals	Study closes

Analytic Process of Phenomenological Analysis

Heuristic inquiry involves a specialized, analytic process of phenomenological analysis. Moustakas (1990) describes five basic phases in the heuristic process of phenomenological analysis: immersion, incubation, illumination, explication, and creative synthesis. First, the researcher becomes totally involved in the world of the experience. Next, the researcher withdraws to permit meaning and awareness to allow space for understanding. Then as understanding grows, themes and patterns emerge forming clusters. The researcher then refines the emergent patterns to unfold new connections. Finally, the researcher is ready to communicate the findings in a creative, meaningful way emphasizing her own personal experiences and insights surrounding the phenomenon studied.

The immersion process for me began a four-month agenda of data analysis. I began by transcribing the interview and focus group discussion tapes. Next, I read and reread the interview and focus group discussion transcriptions. I also read and reread the personal journal entries. I developed a portrait of each participant's experience and wrote a case record for each teacher. After this intense immersion with the data, I retreated from the data analysis for a period of time. This internal incubation period allowed my intuitions and tacit thoughts to clarify and extend the meaning of the data.

The illumination process allowed me to reexamine the original data of the co-researchers and to reflect about my awareness of my discoveries. I rechecked the depictions of each participant and looked for omitted or deleted dimensions of their experiences.

After the emerging themes and patterns were illuminated, I entered the process of explication. I reexamined and refined my own feelings and beliefs and looked again for understanding from the co-researchers' perspectives. After explicating the core meanings and themes from the data analysis of the conceptual change experiences of the research participants, I shared the composite depiction with the participating teachers.

> In heuristic investigations, verification is enhanced by returning to the research participants, sharing with them the meanings and essences of the phenomenon as derived from reflection on and analysis of the verbatim transcribed interviews and other material, and seeking their assessment for comprehensiveness and accuracy. (Moustakas, 1990, p. 34)

I asked the participants to affirm the comprehensiveness and accuracy of the verbatim transcriptions recorded during the interviews and the focus group discussion. My interpretations of their thoughts, meanings, and beliefs about science pedagogy were shared with the participants and I made inquiries about the fit between my depiction of their experiences and the data from which the depiction was developed. The verification process assisted me in portraying and capturing the essence of the teachers' experiences and validated the participants' meanings of conceptual change.

All of the teachers affirmed my interpretations of their conceptual changes about science pedagogy after checking and judging the creative synthesis of the themes and assertions. The participants verified my analysis of their thoughts, meanings, and beliefs and they openly discussed the subjective nature of my depictions from the perspective of a co-researcher.

During creative synthesis, the final phase of heuristic research, the researcher develops "an aesthetic rendition of the themes and essential meanings of the phenomena investigated" (Moustakas, 1990, p. 52). The interpretive work expresses and depicts the passionate, personal stories of teacher change related to my internal frame of reference and connects the depictions to a particular world view of the conceptual change process.

> This judgment is made by the primary researcher, who is the only person in the investigation who has undergone the heuristic inquiry from the beginning formulation of the question through phases of incubation, illumination, explication, and creative synthesis not only with himself or herself, but with each and every co-researcher. (Moustakas, 1990, p. 32)

A Composite Depiction

Five core themes were derived from the individual depictions. "The composite depiction includes all of the core meanings of the phenomenon as experienced by the individual participants" (Moustakas, 1990, p. 52). The five core themes are: teaching and learning in science, teachers as adult learners, the Generative Learning Model of teaching, teacher thinking, and conceptual change. The following group depiction reflects the experiences of individual participants through verbatim excerpts, exemplary narratives, descriptive accounts, and conversations "that accentuate the flow, spirit, and life inherent in the experience" (Moustakas, 1990, p. 52).

Assertions: The Creative Synthesis

The assertions were generated from the study of practicing teachers' thoughts, meanings, and beliefs about conceptual changes in science pedagogy. The assertions emerged through the researcher's awareness of the essences and meanings of the participants through the processes of immersion, illumination, elucidation, and analysis of the data investigated. The following is a synthesis of each core theme interpreted from the creative synthesis of the themes and meanings of the conceptual change experiences.

Teaching and Learning in Science

The initial interviews with the teachers revealed their thoughts, meanings, and beliefs about teaching and learning in science. To study a change in perceptions about science pedagogy, it was important for me to establish the current beliefs and meanings of the participants in the study at the beginning of the academic year. The teachers' beliefs were affected by perceived barriers to change in science teaching. The barriers to change described by the teachers are summarized in Table 4.

Table 4
Barriers to Change

NAME	TIME	RESOURCES	CONTENT	TEXT	TOP-DOWN
Sharon	X	X	X	X	
Chris	X	X	X	X	
Ian	X		X	X	
Eileen	X			X	X
Nancy	X		X		
Cathy	X	X	X	X	
Elizabeth	X	X	X	X	X
Susan	X	X		X	

Assertion 1: Barriers to change in science teaching and learning exist within the constructed perceptions of individual teachers as they relate to the imposed structure of schools.

The participants expressed concerns about time, resources, lack of content knowledge, textbook driven curriculum, and top-down management of schools.

Elizabeth

I'm finding teaching so many more subjects . . . I feel I'm almost being spread so thinly that it's worrying me. I have, I'm responsible now for, of course, English, and reading and spelling and handwriting and math and science. And to prepare to get all of my materials out and ready for my afternoon classes of science is difficult. When I only had math and science, I could think more about the preparation of for the science labs and the science activities. So that does worry me a little bit.... I'm frustrated in the fact that a lot of times teaching science costs a lot of money. (Elizabeth, Initial Interview)

Nancy

Teachers in elementary classrooms need more background help. Biggest problem--background information. (Nancy, Journal Entry)

Chris

I look at our manual and I pick out of it what I want to teach. I do follow their content but what I usually try to do is start out with an activity, do some content, finish up with some type of activity. (Chris, Initial Interview)

Eileen

Regardless of what people say, I still think we're still lock step, isolation, last week we had our board members come in and observe. What do board member expect to see? They expect to see children sitting in their seats quietly. (Eileen, Final Interview)

Assertion 2: Perceived models of teaching science are barriers to change in science pedagogy.

The participants described their current teaching practices in science through their depictions of science teaching models and examples of classroom practices. The co-researchers exemplified their beliefs about science teaching through the descriptions of the models they used to teach science (see Table 5).

Table 5
Models and Methods of Teaching Science

Name	SC	KWL	H-O	LEC	BASICS	LC	I	SM	WS/RA
Sharon			X						X
Chris	X		X			X			
Ian			X						X
Eileen		X	X		X		X		
Nancy		X	X				X		
Cathy	X		X	X				X	X
Elizabeth	X		X				X		
Susan			X		X		X		

SC= supplemental curricula
KWL= know, want to know, learned
LEC= lecture
H-O= hands-on
I= integration
Basics= back to the basics
LC= learning cycle
SM= scientific method
WS/RA= worksheet/read about

When teachers in the study were asked to describe their teaching and to give an example of teaching and learning in science in their classrooms, the participants used many different models in the descriptions. The teaching model or method was often used as a context for explaining and depicting the personal practice of teaching science in the classroom.

Nancy

We've used these charts where we list what we know, we list what we want to know, and then we go back at the end and list what we learned. (Nancy, Initial Interview)

Chris

I think of it as the learning cycle. (Chris, Initial Interview)

Cathy

We might start (the scientific method), I start by introducing, of course, the steps, the five steps.. .Usually I use the subject matter that we've taught (for testing) and you know if you want to call it a lecture. (Cathy, Initial Interview)

Eileen

> I would say I would have more of a tendency to be more of an active hands-on type person when it comes to science. (Eileen, Initial Interview)

Nancy

> What Mrs. Dell and I have done in second grade is try to integrate it in with our reading. We try to do a lot more integrating with the social studies and science because we find that it always seems to get left out because we spend so much time on reading and math as being two major things. So if we sneak a little more in under other names we do. (Nancy, Initial Interview)

Ian

> I always start with the same kind of introduction. The classic, not really classic, but just my way . . . more traditional where you start with a bulletin board and you talk about the obvious stages (of a frog) and the characteristics and then you end up with a worksheet or something . . . (Ian, Final Interview referring to initial practices)

Teachers as Adult Learners

The teachers in this study grew professionally as adult learners throughout the academic year. The staff development workshops removed the teachers from their isolated classrooms and set a climate for collaboration, reflection, and discussion. The participants greatly appreciated the opportunity to share, think, and engage in the construction of knowledge about science pedagogy.

Assertion 1: The personal responses and the growth within the hearts and minds of elementary teachers about science pedagogy synthesize to become the "scientific soul" of the teacher. The scientific soul is the essence of the excitement, curiosity, and exploration of teaching and learning in science.

Nancy

> I guess maybe the whole concept of the GLM model that you know, there is a model out there. There are things you can do. There are stages and that I actually had a chance to see the stages and participate in them, you know . . . . It opened me up to some ideas.

> Because watching you take us through some of the steps as we were the participants and how many different ways a student could take a topic and question it as we had done, opened my eyes to, "gee, I really need more content here, more background." (Nancy, Final Interview)

> *Cathy*

> I learned a lot about science even . . . with your experiments and your activities and things and now I'm excited to involve that. One thing I will say, too, I think that if you have a model that you kind of follow mentally, even if you don't do it step-by-step, it avoids the problem of just doing hands-on just to do hands-on with no purpose . . . so I think if you kind of follow the steps of the model, even mentally, even if you're not doing each one, that it helps to have a purpose for the lesson, too, especially in science. Sometimes it's fun, but you've got to be careful that you're doing it with a motive. (Cathy, Final Interview)

Assertion 2: Collaboration and cooperation in learning environments nurtures one's scientific soul through continued personal growth and dialogue with others.

The participants valued the opportunities to share ideas with the other participants in the workshop setting. The teachers collaborated about classroom strategies during workshop activities. The group focus discussions set aside time for the teachers to voice their opinions and ideas about the GLM and its function in the practice of teaching science in the elementary school classroom. The participants richly described their involvement in the three workshops. Their voices expressed appreciation and enthusiasm for professional development.

> *Cathy*

> I thought it was very, very valuable. I enjoyed it. I wish that all teachers, no matter how long they have been in the classroom, had the opportunity to do things. We've been crying for years to have days that we could observe other science classes, just other teachers, just like us, teaching the same subjects, but to get more ideas and a fresh approach. So I think anytime that you can work with your peers . . . . You know, even Ian and Susan in the

> second grade . . . we can go weeks and not see them except to pass them in the hall. So we have, sad to say, no idea what they have done maybe until we get the third graders and they say, "we did that in second grade," you know. That's very sad, but very true. So I think anytime you can pull professionals together to work and to learn from each other, I think it's very valuable. (Cathy, Final Interview)

Nancy

> You're in one building and you see the people, I see certain people. I'm at the corner and there are always other people. I hardly ever see Elizabeth, you know. I pass her in the hall. So, I don't know exactly all what goes on even in our own building, let alone what goes on in another building. So when you put a bunch of teachers together, the best thing to do is to let them talk because you're going to find out that most schools are the same. They have the same problems and if you can get some new ideas how to work around things . . . . You know, it's good to find out what's going on. You don't feel like you're stuck in a room all by yourself. (Nancy, Final Interview)

The collaborative spirit evident in the voices of the teachers impacted the personal and collegial growth of the individual participants. Each workshop session strengthened the peer relationships and encouraged peers to share ideas and expertise about teaching and learning in science and other curricular areas. An atmosphere of trust, respect, and comfort supported a spirit of risk taking and verified a helping social environment that eliminated feelings of isolation.

The staff development workshops refreshed and revitalized the minds and spirits of the participating teachers. Their scientific souls were nourished by the excitement, enthusiasm, and warmth generated by the group for learning in science. The workshop opportunities introduced the participants to an innovation and supported the investigation and discussion surrounding its implementation and effectiveness.

The GLM

The initial interviews with the participants established a context for each teacher's world of teaching science. Teaching models, the nature of learning, and curricular materials were components of the teachers' perceptions of the context for teaching and learning science.

> Evidently, teachers' beliefs and principles are contextually significant to the implementation of innovations, be they curricular, instructional, or in some other way the outgrowth of research and development in the world of science education . . . . If we are to understand how a teacher might deal with an innovation, then we must first understand his or her beliefs and principles. (Munby, 1984, p. 28).

The GLM was the instructional innovation presented at the three staff development workshops. The innovation presented a dilemma for the participants. It challenged the teachers' current ways of knowing about science teaching and learning and initiated new possibilities for a transformation from current perspectives to new meanings for science teaching. Each individual teacher viewed the GLM through his or her own personal perspective.

None of the participants initially mentioned generative learning or the construction of ideas or knowledge as a principle of or a perception about teaching and learning in science.

Osborne and Wittrock (1983) suggest that experienced teachers need opportunities to clarify the differences between children's ideas, their own ideas, and the ideas of scientists. A suggestion for teacher education programs is "peer group discussions to clarify participants' ideas with respect to each other, scientists, and children" (p. 502).

The focus group discussions carried out at the second and third workshop sessions supported the researcher's interpretations of the understanding and implementation of the GLM by the participants. Two assertions were generated by the participants about the GLM.

Assertion 1: The GLM enfolds teachers in a conceptual change process related to the practice of teaching science.

> *Cathy*
>
> Amazing what knowledge these children come to you with and that can even eliminate some things that you don't have to cover that they already know. So I picked up on that more, a lot more, than I used to do. So, I've appreciated that. (Cathy, Final Interview)

Assertion 2: The methodology of the GLM creates dissonance in the scientific souls of teachers about current practice and contributes to the conceptual change process by providing a context for the depiction of internally changed conceptions.

> *Eileen*
>
> If you were to go into a preschool room where you would see children tinkering, your first impulse is, well, you know, we've been so conditioned to sit down, fold your hands, and stop messing around. Well, maybe they're just not always messing around. Maybe they're beginning to wonder why. And I think perhaps with your more active students and maybe perhaps even with your more discipline problem students, this type of method would work very well because they're engaged and they're thinking. Where the conventional, structured classroom, which we are more in tune with, discourages this type of thing unless we are looking for it in ourselves. From what I've seen of the Generative Learning Model and what we have done, I think it's a very worthwhile way of approaching science. (Eileen, Workshop 3)

In this study, the researcher was the "consultant" or the change agent who presented the GLM in a series of three staff development workshops. Clark (1988) suggests that the consultant should be humble, sympathetic, and service-oriented.

As the relationships between the researcher and the participants developed, the participants became less and less defensive about their former teaching practices. They felt comfortable with sharing ideas and methods to change the practice of teaching science in the elementary classroom.

The learning process surrounding the innovation, the GLM, instigated a period of thoughtful questioning for the participants. They began to think about children's ideas, productive questions, generative learning, constructivism, and science content. Their thinking and reflection about science teaching and learning aroused feelings of discontent with current practices and expressions of dissatisfaction regarding the conceptual learning within their students. The focus group discussion at the workshops provided the setting for voicing concerns and for sharing strengths with colleagues who were experiencing similar conceptual conflicts.

Teacher Thinking

In addition to the discussions about teaching strategies in a focus group, thinking aloud about teaching practices during interviews, and interacting with the researcher through dialogue, the participants in the study wrote reflections in journals. Russell et al. (1988) describe reflection and the role it plays in teacher thinking.

> While reflection may not be a conscious activity, we have seen that, when placed in a situation where reflection and discussion are encouraged and deliberate, most teachers have been enthusiastic about the opportunity this afforded them to think about their work and share concerns with an interested party. (p. 88)

The participants kept personal journals throughout the process of learning about the GLM. They responded to their thoughts, meanings, and beliefs about the teaching and learning of science by writing reflections in their journals and by participating in focus group discussions. The reflections, written and voiced, documented the process of personal knowledge construction for each participant about science pedagogy. The newly constructed knowledge influenced the practice of teaching science in the classroom as described by the teachers in journals, interviews, and discussions.

Assertion 1: Thinking about science teaching and learning occurs amidst reflections about conflicting beliefs and meanings for current practices.

Eileen

> As I think in terms of our meetings, I was caught up in the enthusiasm that everyone showed for science and the exchanges that took place. I appreciated the flow of ideas and the views held by the other teachers. . . . I just found myself, when I wrote this, particularly toward the end, I just asked myself a question and put it in a question and tried

> to think about it. One of the things that struck out in my mind . . . I underlined it here just because a word means one thing to you doesn't mean it means the same thing to everybody. And I think so many times in science and in education, are we really communicating? Are we really understanding what we're trying to say? Is your version, is your thinking different from my thinking? We're seeing the same thing, but we're thinking different things. (Eileen, Journal Entry)

Assertion 2: The personal, contemplative experiences of teachers authenticate teacher thinking about the value of classroom practice in the teaching and learning of science.

As a result of their personal experiences with journal keeping and journal making, teachers began to implement science journals into classroom practice. The personal, thoughtful experiences of the teachers inspired them to support like experiences for their students.

Chris

> And we're doing "electric journals." So after every activity, they have to write. It just could be three sentences, it could be five sentences, it could be a page. But they have to write why they think we did the activity, how it related to static electricity and then we usually take five minutes at the beginning of another class and they share what they had written about the other activity . . . and I just have to remember to give them time to do it sometimes. We, you know, checked it over the other day and everybody was up to where they were supposed to. We did five activities for static electricity . . . . I'll probably do that more next year now that I've kind of got my feet wet on it a little bit and dabbled into that. I can see where a journal will definitely give me feedback from my students. And also, I think that if someone reads something and it's way off key, I'll know that, oh boy, that person doesn't understand what we're doing here. (Chris, Final Interview)

Reflection, an internal characteristic of teacher thinking, and journal keeping, an external characteristic of teacher thinking, contributed to the participants' conceptions about teaching and learning in science. The internal and external characteristics of teacher thinking about science teaching and learning began to convince the participants about the need for instructional strategies which diagnose students' conceptions, ideas, and achievements in the science classroom.

A constructivist view of reflective teaching asks the teacher to reorganize or reconstruct experiences that lead to new understandings. Schön (1988) describes reflective teaching as open to confusion and vulnerability. Reflective teaching parallels the disequilibrium or cognitive dissonance experienced by children during the Generative Learning Model of teaching. Reflections about purpose and meaning, if examined by responsible practitioners, influenced decisions about how to teach. As individual teachers consciously begin to reflect on the meanings of their experiences, they begin to challenge the customs of the education system and to challenge their own traditions of teaching.

Conceptual Changes in Teacher Thinking

The individual teachers' voices and their written reflections documented the personal, conceptual change process for each participant. The rapport established between the researcher and the individual participants and the alliances formed among the teachers and with the researcher supported the investigation of the change process in teacher thinking about science pedagogy. The scientific souls of the researcher and the participants were openly shared and communally encountered through individual and group dialogues.

Assertion 1: Change begins to occur inside the scientific soul of a teacher when current beliefs and meanings about practice are in disequilibrium and new beliefs and meanings for practice begin to make sense.

Changes in methodology, meaning, atmosphere, and thinking influenced the practices of teaching science in the classroom of the participating teachers. As the teachers began to make sense of the Generative Learning Model of teaching and instruction for conceptual change, they began to change their conceptions about appropriate classroom practice.

Ian

I probably in all honesty, I probably would not have done that kind of approach without at least being exposed to that kind of thinking. I would have just opened the file and said,

> "Ok, we did this and we did this and this and filmstrip number four and worksheet one, two, and three, worksheet four, five, and six." Not quite as hard core as that . . .but not quite as open ended . . . . And it was interesting because the people that were in the room, I think I had mentioned to you, and the sub had a feeling of . . . this was exciting. I don't know if exciting was the word. It was fun. (Ian, Final Interview)

Each of the eight participants changed their conceptions about science teaching and learning in some way. Each individual came to the staff development workshops with a unique set of the beliefs and principles for the teaching and learning of elementary school science. Therefore, each participant's meanings and thoughts changed in a particular way. The thoughts about pedagogy and methodology differed in some ways, but the perceptions of teaching and learning in science transformed to include new ways of knowing or making sense of teaching science.

Assertion 2: Changes in the practice of teaching elementary school science are prefaced by a willful change of the conceptions within the scientific souls of teachers.

The process of implementing changed conceptions into classroom practice is a complicated next step. "One can theorize with the best of intentions about how teaching and school learning could be optimized, but the finest ideas and proposals must still pass through the funnel of teacher planning" (Clark, 1988, p. 8). Clark describes the practice of teaching as cognitively demanding and complex. The teachers in the study began to envision their plans in science to include the thoughts and beliefs affirmed in conceptual change teaching.

Elizabeth

> And I think where I need to work more on is what we're doing here with what do you know? What do you need to know? Going back, I don't. I think I'm too much of a dictator. What do *I* want to teach? All these neat ideas. I need to get into more of not being a dictator. More finding out what they already know and what they need to know and I think I am very weak in that area. I like coming to these things (workshops) and kind of keep injecting myself with this and keep bashing and say . . . do this. I like that idea . . . . Well, I think that a lot of people, myself included, before I got into this with you, I was

> saying, "Yes, I do hands-on science" . . . . Yes, I did. But, so what? I mean if I didn't, sure, they were doing a lot of things but if I wasn't having them apply it to see if they really understood the whole concept of what they were doing and . . . I'm not saying I'm at that point yet. I mean, I'm still growing slowly with this. But I can see where that is the whole ball of wax. I mean that is what we really have to do. (Elizabeth, Final Interview)
>
> *Ian*
>
> And that it has to start even before that. I have to change . . . I mean it has to go back further than just the kids changing. I think it's something that you . . . ultimately probably take time to really initiate on a wide scale. (Ian, Final Interview)
>
> *Eileen*
>
> And I suppose not only are we talking here about a conceptual change for the student, but as teachers, we have to undergo a conceptual change and try to influence those people who are in charge of inservicing, curriculum, and so forth, so a change does take place. (Eileen, Workshop 3)

The teachers struggled with their changing conceptions about the teaching and learning of science in the elementary classroom. As the teachers interpreted personal meaning for conceptual change teaching and learning, the conceptual change process occurred within the "scientific souls" of the participants. Teaching and personal changes were intertwined as intensely passionate experiences for the participants. Each individual participant's change process was a unique experience. The change experiences transformed the practice of teaching science to include newly constructed knowledge about teaching and learning in science.

The emerging assertions from each of the five core themes interpreted the conceptual change experiences of the participants. The composite depiction of the group, through verbatim excepts of vivid, accurate, and clear qualities of the core themes, represented the experiences of the co-researchers. Individual reflection and experience with disequilibrium and cognitive dissonance about their familiar routines occurred during staff development workshops and amidst classroom activities and teaching. The struggles with individual conceptions about science teaching assembled together represented the volitional changes in the minds and heart of the group from their experiences. The composite depiction of the group reflects volitional changes in the scientific souls of the participants. The core meanings about teaching and learning in science, adult learning, and teacher thinking voiced by the participants and interpreted by the researcher authenticate the volitional changes in the construction of conceptions about science pedagogy experienced by the research participants.

The Researcher's Scientific Soul

> Our roles as teachers are closer to those of negotiators than to puppeteers or engineers. And even when we succeed in shaping our students' surfaces, unless we touch their souls we will be locked out of their inner lives. Much of contemporary education in both the public school and the university seldom gets more than skin deep. (Eisner, 1995, p.94)

In my present role as a researcher and a university professor, I interpret Eisner's quotation from the perspective of a teacher educator. School change and reform in science education will not happen unless we unlock the inner lives of teachers. Until we touch the scientific souls of prospective and practicing teachers, reform in science education will continue to be a goal, not a reality.

The intent of the initial research plan was not to simulate the design of the GLM. My previously constructed knowledge about the GLM and my beliefs about meaningful learning that resulted from my work with the GLM impacted my work with the participating teachers. The relationship between the GLM and the events of the conceptual change process of the participants is paralleled in Table 6.

Table 6
Events in the Conceptual Change Process Relating to the GLM

GLM PHASES	EVENTS	CONCEPTUALIZATIONS
Preliminary	Initial Interview One-on-One	Revealed current thoughts, meanings, and beliefs about science pedagogy.
Focus	Staff Development Workshops	Experienced motivating activities and new meanings in science education via the GLM and video cases.
Challenge	Focus Group Discussions, Journal Keeping	Discussed, and shared newly constructed knowledge about science pedagogy after personal reflection.
Application	Final Interview	Disclosed volitional changes in conceptions about science pedagogy via descriptions of teacher thinking and examples of classroom practices.

Self-direction, life experiences, reflection, and finally action expressing learning that has occurred are the constructs of a theory for teachers as adult learners. These elements viewed through the constructivist approach to learning built a conceptual framework for interpreting teacher learning and change. When the teachers experienced dissonance in their own thinking about how students learn best, reflected about those conflicting ideas inside their own heads, and then collaborated collectively with other teachers; they made an attempt at changing their practice. Facing and resolving conflict between old and new conceptions of teaching and learning facilitated making sense of classroom practice and promoted meaningful change for practicing teachers.

Recommendations for Reform

The complicated and interactive process of genuine reform in science education begins in the scientific souls of elementary school teachers. Aspects of educational practices affecting the hearts and minds of elementary school teachers include (a) structure and policy of school, (b) methodology of science instruction, and (c) teacher perceptions about science pedagogy. These dimensions of educational practice reflect the conditions for change in teachers' conceptions of teaching and learning science in the elementary school. When teachers are not given opportunities to address and to contribute to the policymaking process regarding educational practices within the structure of school, it becomes extremely difficult for schools to support the conditions for changing teachers' conceptions about pedagogy.

The structures and policies of elementary schools often constrain the growth of the teachers' scientific souls. Time, resources, curricula based on the scope and sequence of science textbooks, and top-down management contribute to the success or failure of the reform process in science education. Structures, policies, and administrators are the components of school culture often in control of the decision making processes that are crucial to the reformation of science education. School leaders many times besiege elementary school teachers with policy changes, new techniques, one-shot inservice programs, and surface-level inspections of teaching performance. Reform in science education will not take place as a result of these approaches as past studies indicate.

Until policymakers and school administrators recognize teachers as curriculum planners and implementers who are at the center of school culture, change in science education will not become a reality. School calendars, budgets, and inservice education opportunities can positively impact the change process in science education. Time and money for ongoing staff development workshops to support teachers as adult learners who question current practices, act as Socratic tutors for colleagues, and reconstruct knowledge about teaching and learning in science will support the conditions for conceptual change in teachers about science pedagogy. Changing school culture is not easy. When leaders and stakeholders recognize teachers' conceptions about science pedagogy as a viable means for revolutionizing science education, reform begins.

Changing meanings, thoughts, and beliefs to make sense of science pedagogy is not intelligible for elementary school teachers who are viewed as technicians and are inspected during the evaluation of their performances. The conceptual change process involves helping teachers generate appropriate meanings for science pedagogy. Recapturing meaning requires time for reflection about past experiences, collaboration with colleagues about dissatisfaction with current conceptions, and staff development workshops offering plausible alternatives for appropriate classroom instruction.

Inciting curiosity in teachers as learners, creating cognitive conflict in teachers' minds, and providing ongoing staff development workshops will bring about a fruitful reform process in science education. The stories of change told by the teachers who experienced the methodology of the GLM in this yearlong research project affirm the potential for volitional changes in the conceptual thinking of teachers about science pedagogy that will enhance and energize the reform process in science education.

The formidable challenge of changing the nature of teaching and learning in elementary school science begins with the teachers themselves. Teachers become agents of change when they are given time and opportunity to reflect during dialogues with themselves and with others and to collaborate with colleagues about the creative process of changing conceptions of pedagogy. When the excitement and joy of teaching and learning in science awaken the scientific souls of elementary school teachers, they begin to reshape the practice of teaching elementary school science. The teachers' newly constructed conceptions about science pedagogy verify and establish a framework for conceptual change in the teaching and learning of science in the elementary school classroom.

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SUPPORTING COMMUNITIES OF LEARNERS IN URBAN SCHOOL DISTRICTS: EVALUATING THE IMPACT OF THE URBAN SYSTEMIC INITIATIVE ON CLASSROOM PRACTICE

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As a result of an abundance of national and international reports on the science achievement of the nation's youth (Jacobson & Doran, 1991; Mullins & Jenkins, 1988; National Commission on Excellence in Education, 1983), science educators are in the midst of large scale reform efforts. The challenges faced by urban schools as they aspire to reform science education are immense. Under the auspices of the National Science Foundation, through the Urban Systemic Initiative (USI), teachers and administrators throughout the Detroit Public School system have been deeply involved in a wide array of professional development activities. Researchers and professional developers in science education recognize that teachers and administrators are often bombarded with new ideas and are in need of sustained, high quality professional development (Haney & Lumpe, 1995; Holmes, 1986, 1995; MAA, 1991; NCR, 1996; NCTM, 1989, 1991; Raizen & Miachelsohn, 1994; Shroyer, Wright, & Ramey-Gasser, 1996). Furthermore, the likelihood of professional development experiences positively impacting classroom teaching and learning will increase with the development of collegial support (Dlugosh, 1993; Donivan, 1993; Keys and Golley, 1996; Ramirez-Smith, 1995; Sparks & Loucks-Horsley, 1990; Tippins, 1993; Weir, 1992).

One of the first activities at the onset of the Detroit Urban Systemic Initiative (DUSI) involved creating a document which articulated some of the principles of teaching and learning that might ultimately improve student understanding and achievement. This document, *A Constructivist Vision Towards Teaching, Learning, and Staff Development* (Stein, et. al., 1994), has served to inform administrators, teachers and staff of the DUSI vision for improvement. A key challenge in large urban districts is to help all stakeholders understand and work toward common goals. This constructivist vision document has served as a template for professional developers and school teams as they plan for future activities. The nine principals outlined in the document are:

- Each student must actively construct her or his own meaning in order to understand the material being learned.

- Learning depends on the previous understandings that students bring to the learning situation.
- What, and how much, is learned depends on the context in which it is learned.
- What is learned depends on the shared understandings that students negotiate with the teacher and with each other.
- Constructivist teaching involves meeting students "where they are" and helping them move to higher levels of knowledge and understanding.
- Teachers can use specific teaching methods to facilitate student's active construction of knowledge.
- In constructivist teaching, the teacher emphasizes "learning-how-to-learn."
- The constructivist teacher uses continuous assessment to facilitate learning.
- Constructivist teachers are themselves constructivist learners.

In order for DUSI reform efforts to succeed, it has not only been important for teachers to understand DUSI goals, but also for teachers to articulate their own ideas about teaching and learning and to think about changes that are needed for success. Several researchers support the idea that teacher beliefs are precursors to change and that the teacher is the crucial change agent in paving the way to reform (Ajzen & Fishbein, 1980; Crawley & Koballa, 1992; Cuban, 1979; Fullan & Miles, 1992; Jenlink, 1995). Additionally, some researchers have noted that previous attempts at science reform fell short of successful change because they were not systemic in nature and often embodied a top-down model of change (Anderson & Mitchener, 1994; Bybee & DeBoer, 1994; Cuban, 1990; Fullan & Miles, 1992; Gordon, 1993; Sashkin & Egermeirer, 1992).

A key component of the Detroit Urban Systemic Initiative (DUSI) is a summer institute developed to target constructivist teaching and learning principles. During the institute, school teams of teachers and administrators were engaged in a variety of program activities designed to help them to understand constructivism and form supportive communities of learners as they discussed their understandings and developed future plans. It was thought that institute participants who were immersed in a constructivist environment, would have opportunities to confront their own beliefs about teaching and learning and implement changes at the classroom and school levels (Deighan, 1992). Furthermore, the institute was designed to encourage collaboration, the sharing of ideas, and the development of teacher support systems. It is believed that teacher belief systems are significant factors in motivating a change in teaching behavior and that previous reform efforts largely ignored the influential nature of teacher beliefs on changes in teaching practice (Tobin, Tippins, & Gallard, 1994).

A study by Haney, Czerniak, and Lumpe (1996) further articulated the importance of teacher beliefs on changes in practice:

> In other words, teacher perceived outcomes regarding the behavior at hand and the likelihood that these outcomes will occur to be major influences on behavioral intention; therefore, contemporary reform cannot afford to ignore the importance of such beliefs. . . . The obstacles and enablers that the teachers were provided mattered less to them than did their beliefs about the positive and negative outcomes associated with the behavior. This finding suggests that teacher training should pay particular attention to the attitudes teachers have toward behavior before alterations of control factors (such as providing curriculum materials, reducing class size, including flexible class scheduling, etc.) are expected to lead to lasting changes in classroom practice. (p. 985)

Although targeting teacher belief systems may be viewed as critical to change, there are many other obstacles that may impede progress. Sparks (1994) made recommendations for effective, sustained, high quality staff development. The developers of the summer institute sought to adhere to these recommendations. Among the recommendations that were interwoven into the design and format of the institute were:

- Keep the focus on student learning.
- Recognize that change affects staff members in personal ways.
- Change the organization's culture at the same time that individual teachers and administrators are acquiring new knowledge and skills.
- Use a systems approach to change.
- Apply what is known about the change process to the improvement effort.
- Recognize the subtle tension between the importance of establishing readiness for change and the need to get people to try out new practices.
- Provide content-specific staff development that addresses both deeper forms of content knowledge and instructional strategies most effective in that discipline.
- Make certain that learning processes for teachers model the type of instruction that is desired.

- Provide generous amounts of time for collaborative work and various learning activities.

Description of the Program

As part of the Detroit Urban Systemic Initiative (DUSI), a massive professional development institute was held during July, 1995 and 1996. The institute, Building Communities of Learners for Mathematics and Science Literacy, attracted over 1300 applicants each year. The goal of the institute was to foster school-based peer support as school teams worked together to improve the mathematics and science programs offered to students. A constructivist orientation was central to the institute design. The institute was able to accept over 700 participants in 1995 and 800 participants in 1996. The participants were comprised of school teams of mathematics and science teachers and administrators across grade levels (K-12).

Presenters at the summer institute represented many different universities, institutions, and organizations. Nationally known programs and presenters with national reputations were strong components of the institute. Many of these experts were asked to act as consultants at the institute because their work has been highly regarded in the field. Most of these experts had previously worked with the district and continue to do so. A unique aspect of the institute was to have so many constituencies working together for a sustained period towards a common goal.

The needs of individual school teams and individual participants varied greatly. Therefore, the program sought to offer participants the opportunity to immerse themselves in a variety of areas. Throughout each day of the institute, participants were involved in four major activities: focus sessions, a keynote address, workshops, and school team meetings. These components of the institute targeted a variety of topics including the following: technology, alternative assessment, cooperative learning, multicultural mathematics and science, Family Math and Science, and specific content workshops related to the Detroit Public School Core Curriculum. The Core Curriculum in aligned with Michigan State and National Standards.

The morning focus sessions provided participants with the opportunity to study one area of interest for the entire week of the institute (with the same participant group and instructor). The focus sessions were followed by the keynote address, during which all institute attendees came together to hear a common message delivered by a speaker of national prominence. Afternoon workshops provided participants an opportunity to explore areas of interest outside of their focus session topics. Finally, each day concluded with school team meetings during which participants discussed what they were learning and made plans for changes during the coming school year.

While participant programming was varied to meet individual needs, the focus of the institute was on constructivist approaches to learning and teaching. During the institute, school teams read and discussed the DUSI vision document, *A Constructivist Vision Towards Teaching, Learning, and Staff Development* (Stein, et. al., 1994). Presenters were also asked to familiarize themselves with this document and to consider how their sessions model and inform principles of constructivism. School teams were encouraged to connect what they were learning through focus sessions, keynote addresses, and workshops to the principles of constructivist teaching that are outlined in this document. It was believed that this alignment of activities would help to further DUSI goals. During the institute, school teams were asked to work together to create a "Team Action Plan" (Appendix A) which would detail goals and implementation plans for their science and mathematics programs for the 1995-96 school year. Each school team submitted a team action plan at the end of the institute.

Methods

Several types of data were collected to examine the impact of the summer institute activities on institute participants. At the conclusion of the institute, a survey was administered to evaluate the effectiveness of each of the program components. The "Team Action Plans" developed by each school team participating at the institute were also utilized as a data source. Many school teams also provided brief reports that served to update the institute coordinators on the progress the team was making toward implementing their action plans and achieving their goals. Finally, as part of the overall Detroit Urban Systemic Initiative Evaluation, eight case studies of school teams who had attended the institute were conducted. As part of the case studies, semi-structured interviews were conducted with each school team. Institute surveys and interview transcripts served as the primary data sources.

A survey was administered to all institute participants at the end of the summer institute. Participants were told not to identify themselves on the survey. The survey utilized a five point Likert Scale with a rating of "1" indicating "Strongly Agree" and a positive response while a rating of "5" indicated "Strongly Disagree" and a negative response. All items were positively phrased.

To obtain information on the quality and nature of the changes reported by school teams, eight school teams were selected for in-depth study. The schools were selected to mirror important characteristics of the summer institute teams. The majority of summer institute participants were elementary level educators. Thus, five of the eight case study schools were at the elementary level, with two case study schools each at the middle and high school levels. Each of the school teams had articulated changes that were occurring at their schools through interim reports.

The primary objective of gathering data through case studies of selected school teams was to obtain detailed evidence regarding the extent of the quality of change in the science and mathematics program as a result of the implementation of the team plan. Additionally, the researchers wanted to document obstacles or barriers encountered by the team and how they were resolved.

Science and mathematics educators from Wayne State University conducted the case studies. These researchers were familiar with the summer institute goals, the Team Action Plans, and the DUSI Constructivist Vision Document. Each researcher visited the school sites, held discussions with administrators and teachers, and made classroom observations. A semi-structured interview with school team participants focused on implementation of the Team Action Plan (Appendix B).

The methods employed in the case studies were interpretive (Erickson, 1986). Sources of data were transcripts of eight in-depth, semi-structured interviews of approximately one hour duration each and field notes of lesson observations, informal conversations, and observations of student work. The use of multiple data sources helped enhance the credibility of findings. Lincoln and Guba (1985) indicated that the use of multiple data sources in data analysis, called triangulation, allows the researcher to test emerging assertions against the entire data set to confirm or refute those assertions. Compatible with the type of data yielded by interpretive case studies, inductive analysis (Bogdan & Bicklen, 1992; Marshall & Rossman, 1989; Merrieam, 1988) was the primary method for analyzing the data. That is, the data were repeatedly examined to uncover salient patterns, singularities, and themes. Emergent relationships and assertions (or working hypotheses) were then generated. These assertions were tested for validity against the entire data set and reformulated as the analysis developed.

Results

At the end of each institute, a survey was administered to institute participants. The survey results are shown in Table 1. The results indicated that institute participants believed that the institute was very worthwhile and that their was a strong likelihood that the Team Action Plans developed at the institute would be implemented during the following school year. Survey results also indicated that participants believed that they understood constructivism much better as a result of their participation at the institute. The survey also demonstrated the perceived benefit of planning team meeting time into the program. Survey results indicated that participants believed that team meeting time provided during the daily program was beneficial and helped school teams with future planning. Furthermore, results also indicated that the team meeting time helped individuals think about components of constructivism.

Evidence from the case study reports indicates that as a result of institute activities there appears to be a greater emphasis on hands-on instructional approaches, integrating technology into programs, increasing parental involvement, instituting more cooperative learning, increasing the depth of understanding in content areas, and using a variety of assessment strategies to inform instruction. The case study reports delineate the school curriculum changes planned by the various teams, namely:

- School A focused on increasing students' understanding of estimation and measurement concepts;
- School B focused on increasing parental involvement;
- School C School focused on alternative assessment, technology and parental involvement;
- School D focused on increasing parental involvement, problem solving, self assessment, cooperative learning, and infusing technology;

- School E focused on shifting to more child-centered approaches to instruction and attending to issues of equity in mathematics and science;
- School F focused primarily on parental involvement and an increase in active learning strategies;
- School G focused on cooperative learning, the infusion of technology and increasing hands-on activity;
- School H focused on implementing the Core Curriculum and utilizing alternative assessment strategies.

These activities mirror many of the components found in the constructivist vision document as well as the initial action plans formulated by the teams. Interview transcripts supported the impact of the summer institute on various components of constructivist teaching and learning. The teaching and learning changes taking place that were most evident along with selected supporting data are found below.

Comments that suggested active, student-centered teaching and learning activities included:

> One way that [constructivism in the team action plan] has been reflected is that we have put a greater emphasis in math and science on manipulatives. In science, we see teachers doing less reading of the textbooks and more investigation.
>
> The summer institute really helped me to focus on giving the kids hands-on things to do, to inspire them to learn, to involve them in their learning and it demonstrated to me that this moves kids to higher levels of learning. When the children put their hands-on something, build something, construct something, they're actively involved in learning. That's when learning takes place. Being a new teacher it really helped me. It really helped me get a handle on and to focus on what I ought to be about the business of doing. How I really ought to direct the children and how I ought to facilitate their learning. Being a facilitator of learning, rather than lecturing from the book.

Comments that suggested increased parental involvement included:

> One of the things that happened, that was just fantastic was the Family carnival...Students started showing their parents how to do it [a graphing activity]. I think this is wonderful because it lets the parents see that 'Yes- my child is involved in school and I can help my child out at home.' That was a result of the summer institute that directly impacted this school.

> I think parents are more excited about what's going on in our classrooms - what kids are learning and how they're learning.

Comments that suggested emphasis on student achievement in mathematics and science included:

> I wanted to show you that we have had a tremendous increase in our MEAP math scores this year [shows newsletter report]. We are involved in the Metropolitan Achievement Testing right now. And I think we will see some significant improvement in scores because of all the hard work.

Comments that suggested cooperative and collaborative teaching strategies included:

> In my case, its a completely different approach [to teaching]...I use technology the best I can in order to get the kids to start their own learning by involving them. I'm not sure how much learning is taking place, that will come later, but I know everybody is involved because they all have to be involved. Not just through the pressure of my direction, but the peer pressure of being involved like everybody else. So you get more activity. And sometimes somebody else might come in and think it's noise, but it's not noise. I don't have much of that. For the most part if the noise is constructive and moving towards the objective, then it's doing what you want it to do. In my case that is a big change.

Comments that highlighted the importance of professional collaboration included:

> Team planning is excellent in this building. Everybody puts their heads together and thinks about what is we need to do and then they go ahead and do it.
>
> A lot of times [the principal] has the vision and then we work together to make it happen. Most of the time her visions are good. A leader with a vision is most important.
>
> The week before school opened we had a five day workshop with our teachers. One of the days, the team members who attended the institute presented all of the materials that we received. And we made copies. So even though most of our staff did not attend the institute, that information was disseminated.

Survey and case study results indicate that the summer institute may have helped participants implement changes at individual, classroom, and school levels. While the case studies provide information on only a small sample of schools, the results indicate that it is possible that even when school level changes are not evident, individual participants may still be profoundly affected and begin the change process on a personal level. This was evident in candid interview comments as shown in the example below:

> In my classroom I think it's student activity - the student interaction. It's the biggest change in my room. I guess that change came from me. I didn't see the value of it too much before because I thought it was noise. I didn't think noise was productive. But I think different now from the workshop I went to. I talked with some of my colleagues, and watched what they do, and then I started...I think that was the biggest change for me - getting the students involved in their own learning.

Summary and Conclusions

The results of this study indicate that the Summer Institute program has had some very positive impacts on the ways educators provided science and mathematics instruction to their students. Key components of the institute that enabled this success were:

- adherence to an articulated, shared vision which permeated program activities;
- a variety of sessions designed to meet a diversity of individual and school needs;
- effective consultants who modeled constructivism in their presentations;
- teams composed of teachers and administrators who would support the team action plans
- a focus on student learning outcomes;
- time for school team sharing and planning built into the program.

Time for participants to share and plan for the future was a critical component of the institute. The Team Action Plans served to remind the teams of their goals and the activities that would be needed to reach these goals. Each school team might be viewed as a "learning community" where team members shared their views and formulated plans together. At the same time, other kinds of learning communities also seemed to emerge through the selection of specific morning focus sessions.

Many urban, state, and national reform efforts are looking for ways to scale up to meet current professional development needs. The challenges faced by urban schools as they aspire to reform science education are immense. At the same time, there is a need to develop collegial support at the building level in order for reform to take place. The format of the DUSI summer institute targets and supports these two objectives and may serve to provide other staff developers with ideas to support their efforts.

Table 1

Survey Evaluation of Summer Institute by Teacher and Administrator Participants

Survey Item	Participant Group	Number of Teachers Responding	*Average Rating
The format of the institute was well designed (Focus Session, Keynote, Workshop, Team Meeting)	1	149	1.58
	2	213	1.46
	3	189	1.50
The form group session modeled constructivist teaching.	1	151	1.34
	2	221	1.38
	3	189	1.22
Team meetings were beneficial.	1	145	1.58
	2	221	1.43
	3	187	1.56
Team meetings helped us with future planning.	1	147	1.50
	2	220	1.35
	3	188	1.48
The likelihood of our team implementing the plan is very good.	1	145	1.58
	2	220	1.41
	3	188	1.49
Team meetings helped our team to think about components of constructivism.	1	148	1.53
	2	219	1.40
	3	187	1.44
I understand constructivism much better as a result of the institute activities.	1	148	1.41
	2	222	1.36
	3	189	1.36
Overall, the institute was a valuable experience.	1	148	1.23
	2	222	1.20
	3	191	1.27
If given the opportunity, I would like to attend this institute again.	1	147	1.25
	2	222	1.26
	3	187	1.27

1 = strongly agree and a rating of 5 = strongly disagree

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Appendix A

Team Action Plan

School ____ Area______

Team Members in attendance who also attended the 1995 Summer Institute: ____

Team Members in attendance who **did not attend** the 1995 Summer Institute: ____

Team Leader(s) ____

The purpose of this form is to help you determine what actions your group wants to take in implementing strategies for mathematics and science reform in your school. After you have completed the form, it should be turned in to the facilitator.

1. **Describing Science and Mathematics Education at your School**: How does science and mathematics education fit within your school improvement plan? What are strengths and weaknesses of the current program? What changes are most needed?

2. **Reflecting on Current and Past Plans:** What improvements does the team envision for science and mathematics instruction? If your team attended the summer institute last year, what were your accomplishments? If your team did not attend the summer institute, what changes have recently been implemented in an effort to improve mathematics and science teaching and learning?

3. **Identifying Your Goal**: What do you want to accomplish?

4. **Activities**: What activity(ies) will enable you to accomplish your goal?

5. **Details of Plan:** Describe what you plan to do in some detail.

What specific activities does your plan involve?

Who is responsible for each activity?

When will planning/preparation tasks need to be completed?

When will the activity(ies) actually take place?

Who needs to be involved in the planning to ensure success?

6. **Resources:** What resources, including human resources, do you need to carry out your planned activity(ies)?

7. **Challenges:** What do you see as the greatest challenges you will encounter in carrying out your plan? How will you overcome them?

8. **Benchmarks:** How will you know if you've been successful?

9. What would you like to say six months from now about your plan?

10. Next November or December, each team member will be contacted to complete a brief report on the team's progress and accomplishments as the action plans are implemented. What is the **name and telephone number** of a person who is willing to take responsibility for facilitating this feedback process? What is the best time to call?

Appendix B

Case Study Interview Questions

1. To what extent did the team action plan reflect a **constructivist vision**? To what extent did the team action plan reflect a **standards-based curriculum**?

2. To what extent were **teachers/administrators** implementing the action plan developed in the summer institute?

3. What **artifacts** from the implementation of this action plan **provide evidence** of a **constructivist orientation** toward teaching and toward the **Core Curriculum** in mathematics and science?

4. What **changes in student learning** occurred as a result of this team action plan? **Evidence**? (Look for such items as student projects, lesson plans, student portfolios, observations, interviews with team members, documents, school improvement plans, action plans, reports, and other relevant information.) **Obstacles** or **barriers**?

5. What **support** did you get for implementing your action plan? **Where** did the support come from? What support was **most helpful**?

6. What were the most **essential elements** of your team's success?

7. What **effect** did the implementation of your team action plan have on **others** in your **school community**?

8. What **additional professional development opportunities** that **supported your team action** plan have you had since the summer institute?

SYSTEMIC REFORM EVALUATION :
GENDER DIFFERENCES IN STUDENT ATTITUDES TOWARD SCIENCE AND MATHEMATICS

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Background Information

In 1994, a large urban school district embarked on a systemic reform effort for its science and mathematics programs. This reform effort collaboratively involved all aspects of the community including teachers, students, administrators, parents, university science and mathematics educators, scientists, and community/industry representatives. A constructivist vision statement was initially developed to guide this change process. It essentially stated that constructivism leads to new beliefs about excellence in teaching and learning and discussed the roles of both teachers and students in the process. Furthermore, in constructivist classrooms students are active rather than passive; teachers are facilitators of learning rather than transmitters of knowledge.

Both formative and summative evaluations were undertaken each year to inform leaders and teachers about progress and needs. A combination of data collection techniques were used: achievement tests, teacher surveys, student surveys, case studies, focus groups, and observations of staff development sessions.

Problem

One of the underlying emphases of this systemic reform effort was that of gender equity. That is, all students should be encouraged to learn science and mathematics in every year of their schooling from elementary school through high school. Furthermore, all students should be encouraged to contribute to class activities in science and mathematics—cooperative learning methods were encouraged. Teachers were asked to develop and use practices that fostered equity in the classroom. Staff development activities over a two-year period emphasized ideas and modeled techniques for better achieving equity in learning.

Purpose

The primary purpose of this study was to gather baseline data on gender differences in student attitudes toward science and mathematics as a part of Systemic Reform Evaluation and to see whether this systemic reform effort had enhanced student attitudes toward science and mathematics for both boys and girls. This data will be useful as formative evaluation for curriculum leaders and other supporting personnel involved in this reform effort. Based on this data, changes can be made in the inservice and preservice program for teachers and in other aspects of the science and mathematics program. Knowledge of possible gender differences in student attitudes toward science and mathematics can assist teachers in their mission to help each child become a more capable learner. Furthermore, future evaluators of student attitudes can use this baseline data for determining if progress has been made in the systemic initiative on achieving gender equity.

Review of the Related Literature

Overview

Historically, research on science education has focused on specific educational outcomes. Until about twenty years ago, the major focus of this research was on educational objectives in the cognitive domain. Recently, the affective domain, as defined by Krathwohl, Bloom, and Masia (1964), has not only been accepted as a relevant part of education, but has also become the focus of considerable research. One of the key variables within the affective domain that has drawn attention is attitudes.

The relatively low number of women in scientific professions has become a national concern. It has been proposed that the attitude of girls toward science is one factor that influences the decision of girls to participate in science as well as their achievement in science. This concern has resulted in a variety of studies designed to identify gender differences that may effect the number of girls in the scientific pipeline (Oakes, 1990).

Some observers have suggested that gender inequality is no longer an issue in education because gender differences in educational achievement have declined considerably over the past decade (Archer & McDonald, 1991; Friedman, 1989; Marsh, 1989; Viaredo, 1991). Wilder and Powel (1989), in "ETS Policy Notes", suggested performance differences may be slowly diminishing, although women still lag in some aspects of spatial ability and achievement at the top levels of mathematics.

However, Catsambis (1995), using data from a large, nationally representative sample of approximately 1,052 schools and 24,500 eighth grade students, suggested that the decline of gender differences in achievement may not be sufficient to ensure the increased participation of women in scientific and technical fields. Catsambis found that, in the middle grades, girls do not lag behind their male classmates in science achievements tests, grades, and course enrollments; however, twice as many boys as girls reported science career aspirations and positive attitudes toward this subject even among students of similar levels of achievement. The American Association of University Women (AAUW) (1992) carried out a survey of 3,000 fourth through tenth grades students, girls and boys from across the country (12 locations nationwide), in order to examine the impact of gender on self-esteem levels, career aspirations, educational experiences, and math-science interests. AAUW found similar results as Catsambis, although girls received equal or even better grades in science and mathematics courses. However, as girls grew older, they lost confidence in their abilities, and showed less interest in these subjects than boys in high school. Baker (1983) also found girls to have more negative attitudes toward science than boys, but still to have higher science grades.

Gender differences in scientific and technical careers are, therefore, largely due to attitudes and choices of a science-related careers and not so much due to levels of achievement. Catsambis reasonably concluded that gender differences will continue to persist in our nation's scientific pipeline because of the importance of early commitment to scientific and technical fields.

Gender Differences in Attitudes Toward Science and Mathematics

There are numerous researchers who found that, particularly in the U.S., boys held more positive attitudes toward science than do girls (Czerniak & Chiarelott, 1984; Kahle, 1983; Kurth, 1987). Lowery, Bowyer, and Padillia (1980), in their experimental study, reported that boys showed more positive attitudes toward science than girls in both the control and the experimental groups. Kahle (1984) reported that data from the National Assessment of Educational Performance (NAEP) had indicated that 13- and 17- year-old girls had strong negative attitudes toward science and had little belief that the discipline could be useful to them. Likewise, Zimmerer and Bennett (1987) found that both eight-grade boys and girls enjoyed doing science experiments, but that boys were more enthusiastic than girls. Similarly, Simpson and Oliver (1985), in their multidimensional study among approximately 4,000 students across grades (6th-10th), found that boys exhibited significantly more positive attitudes towards science than girls within each grade level as well as across the grades. Schibeci and Riley (1986), using a National Assessment of Educational Performance (NAEP) data set, examined the influence of five background variables: sex, race, home, environment, amount of homework, and parents' education, on three dependent variables: student perception of science instruction, student attitudes, and student achievement. They found that gender had an influence on attitudes and achievement, with girls having less positive attitudes than boys. The NAEP indicated that boys have tended to have a more positive attitude toward science than girls and that this trend had changed little over time (Mullis & Jenkins, 1988). In a meta-analysis of the literature from 1970 to 1991 among 31 effect sizes representing the testing of 6,753 students (3,337 boys and 3,416 girls) in 18 studies, Weinburgh (1995) examined gender differences in student attitudes toward science, and correlations between attitudes toward science and achievement in science. Results of this meta-analysis indicated that, from 1970 to 1991, boys had consistently shown a more positive attitude toward science than girls. This had not appeared to change over time.

On the other hand, several researches indicated no gender differences in attitudes toward science and mathematics. Germann (1994) reviewed studies (Fleming & Malone, 1983; Wareing, 1990; Simpson & Oliver, 1990) that indicated that there appears to be little or no relationship between gender and science attitude. Shepardson and Pizzini (1994), in their study among 268 middle school (7th and 8th grades) students, investigated the perception toward science activities and science achievement of boys and girls in middle school life science, and the results indicated no significant difference in perception by gender at middle school level study. Houtz (1995) compared two types of instructional organization strategies' effects on science attitude among 570 seventh- and eighth-grade students within one school in an urban district in the Midwest. A proportionally stratified, randomly selected experimental group used the middle school interdisciplinary team strategy. The comparison group consisted of the traditional junior high science instructional strategy. The results revealed no significant differences between the attitudes toward science as a school subject of boys and girls, regardless of the instructional strategy. Barrington and Hendricks (1988) also found no gender differences with respect to attitudes toward science with gifted and average students.

Some research showed, moreover, that girls have more positive attitudes toward science and mathematics than boys. Although it appears that, in general rather than in a specific discipline, boys have a more positive attitude toward science than girls, Schibeci (1984) reported in a narrative review of the literature that girls showed a more positive attitude toward biology, whereas boys showed a more positive attitude toward physics and chemistry. Moreover, Baker (1985) found that middle school girls in his study had significantly higher attitudes than did boys.

Gender Differences in Attitudes Toward Science and Mathematics with Respect to Level of School

Many researchers found that gender differences in attitudes toward science and mathematics vary as students move from elementary to the high school level. Cannon and Simpson (1985), in reports on a comprehensive, longitudinal investigation among 821 adolescent students, found that a positive attitude towards science deteriorated throughout the school years. Hueftle, Rakow, and Welch (1983) found that attitudes toward science became more negative during the middle school years. Middle grades comprise the stage when students formulate their gender identities and career aspirations (AAUW, 1992; Oaks,1990; Sadker, M., Sadker, D., & Klein, 1991). This stage of schooling represents an important opportunity for encouraging students to consider scientific careers.

Research studies indicate that pertaining to elementary school students, gender differences in science achievement tests, grades, or attitudes do not exist. Gender differences in test scores, course work, and attitudes emerge in the middle grades and become heavily pronounced by the time students reach their senior year in high school. In the middle grades, gender differences begin to appear in attitudes toward science; boys are more likely than girls to find science interesting or to envision that they will use mathematics and science as adults (AAUW, 1992; Lockheed et al., 1985; Oakes, 1990). By high school, few young women consider quantitative and science-related careers to be desirable options. Young women also have relatively high levels of performance anxiety and little confidence in their quantitative abilities and they attribute their success to luck rather than their own efforts and abilities (Cross, 1988; Fennema,1984; Fox, 1980; Linn & Hyde, 1989; Lockheed et al., 1985; Norman, 1988; Schronberger, 1980). Linn and Hyde (1989) cited studies (Dossey, Mullis, Lindquist, & Chambers, 1988; Eccles, 1984; Eccles, Adler, & Meece, 1984; Grandy, 1987; Hilton & Berglund, 1974; and National Science Board, 1987) that provided evidence that boys and girls shared equal interest in mathematics and science in the elementary grades but that boys had a greater interest by the end of high school; these differences persisted through the 1980s and continued enrollment in science and mathematics courses was a result of the subject's perceived usefulness, which means girls continue to have restricted views about the usefulness of science for their future.

Gender Differences in Attitudes Toward Science and Mathematics with Respect to Constructivist Approach

There are several researches who have investigated how the constructivist approach effects boys and girls' attitudes toward science and mathematics. The learning situation can affect the attitude students develop toward science (Hofstein, Scherz, & Yager, 1986; Kulm, 1980; Talton & Simpson, 1987). Although there is evidence that boys benefit more from traditional instructional activities, whereas girls benefit more from cooperative and hands-on activities, the evidence is inconclusive (Oakes, 1990). Kahle (1990) has stated that inquiry-oriented instruction has the potential of producing equitable outcomes in attitude and achievement, and Glaton (1981) concluded that girls prefer inquiry-oriented instruction.

Summary

Despite the numerous findings documenting gender differences in science-related attitudes, the conflicting results from different studies make it difficult to determine whether, in general, there are gender differences in student attitudes toward science (Weinburgh, 1995).

Weinburgh (1995) noted in his meta-analysis several implications for further research. One was the practical need to continue research that examines strategies in the classroom for improving all students' attitudes toward science, especially those of female students, another was the need to continue research that examines attitudes, gender, and grade level. Research needs to address the question of when attitudes begin to decline and then try to determine why they do so. Oakes (1990) strongly suggested we need additional basic research on how individual factors, such as self-efficacy and anxiety, may be linked to gender. It is important to monitor overall trends in the status of women in science and mathematics and to translate these data into indicators that are accessible to policy makers and educators (Oakes, 1990). Oakes (1990) also stated we need research documenting which special intervention programs developed by schools in mathematics and science have effectively increased persistence in scientific and mathematics choices among girls and women.

Methodology

This is a descriptive study which investigates the student attitudes toward science and mathematics of boys and girls in a large school district in mid-west region where a systemic reform effort has been undertaken.

Study Population—Sample

The sampling plan utilized was a disproportionate stratified random sample to represent school levels (elementary, middle, and high school), and tiers (I, II, and III, which represented classification of schools by degree of phase-in of systemic reform efforts). Tier I received in-depth implementation of systemic reform efforts in 1994-95, tier II in 1995-96, and tier III in 1996-97. The sampling plan was developed to ensure random selection and provide reasonably good size samplings. A three stage sampling process was used. The first stage consisted of randomly selecting fifty four schools by tier (10 elementary, 5 middle, and 3 high schools for each tier). For the second stage, the principal of the elementary school, the mathematics and science unit head at middle school, and the mathematics department head and science department head at the high school were asked to randomly select two homerooms/classrooms from their school. At the elementary level, fourth grade students were surveyed, eighth graders for middle school, and tenth graders for high school. The third stage consisted of surveying all of the students in these selected homerooms/classrooms. Given this scheme, a total of fifty four schools were sent surveys with an estimated 1,080 students approached to complete the questionnaire. Completed questionnaires were received from 815 students totaling a 75 % response rate.

Data Collection—Instruments

A survey was conducted to gather information from students about instructional practices used and attitudes toward science and mathematics, and was also conducted to solicit suggestions for improving these programs. The twenty-four item attitudinal section of this survey developed by Wayne State University will be the focus of this research paper. This survey instrument employed a Likert scale for attitudinal measurement. Each item contains four response levels: strongly agree, agree, disagree, and strongly disagree. The response levels were weighted according to their positive attitudes toward science and mathematics, ranging from four (most positive) to one (least positive).

According to item-total summary statistics and Cronbach's alpha, the reliabilities for Attitudes about Mathematics section, Attitudes about Science section, and these sections combined, were found to be .61, .66, and .73, respectively; however, a pair of item statements "I don't worry about how well I will do on math tests" and "I don't worry about how well I will do on science tests" indicated poor correlation between item and total scores for the remaining items. By nature, these item statements are very ambiguous; students could reply to these statements by indicating either a positive attitude (confidence) or negative attitude (carelessness). Therefore, an attempt was made to improve scale internal consistency by removing these two items with low item-total correlations (i.e., correlations between a certain item and the rest of the scale excluding that item) in analyses by item. We decided, however, to include these items in analyses by factor, because these items loaded highly on an important factor, suggesting that it would be premature to discard them from these analyses. After excluding these items, the reliabilities for Attitudes about Mathematics section, Attitudes about Science section, and these sections combined, were found to be .69, .71, and .79, respectively, which was considered to be at an acceptable reliability level, since a guideline often used is to require alpha to be .70 or above (Rodeghier, 1996).

For the purposes of implementing the Systemic Initiative, the entire school district was divided into three tiers which consisted of constellations (elementary, middle, and high school) of schools. The number of schools in each tier vary in size, for example, tier I has the smallest number of schools and tier III has the largest number of schools. In order to insure that there would be representation from schools from all tiers, schools were selected disproportionately to their proportion in the population of schools. To represent the entire district, respondent groups were weighted across tier and school level; we can ensure that each group (by level and tier) is represented proportionately to its distribution within the population by maintaining the same ratio of school level and tier.

Data Analysis

All analysis were conducted using SPSS.

Summary of dependent and independent variable definitions are displayed in Table 1.

Analysis by item.

Because the same variables are measured for each subject (mathematics and science), we conducted a repeated measures design for Multivariate Analysis of Variance (MANOVA) by Gender, Level, Tier, and Subject. In a repeated measures design for Multivariate Analysis of Variance (MANOVA), "Within-Subjects Factor" distinguishes measurements made on the same case to specify a doubly multivariate repeated measures design (more than one variable is measured at each combination of the factor levels); "Between-Subjects Factor" divides the sample into discrete subgroups. Pillais Multivariate Test of Significance are employed for F statistic. Eleven pairs, twenty-two items were analyzed with a 2 x 2 x 3 x 3 (Gender x Subject Area x Level x Tier) repeated measures MANOVA, with subject area (mathematics and science) serving as the within-subjects variable and with gender, level, and tier serving as between-subjects variables.

This analysis was done across all pairs of items. Further analyses were conducted at the individual item level when the overall F was significant. This is a case of a 2 x 2 x 3 x 3 factorial analysis; therefore, there are fifteen related hypotheses that we can test in this design.

Analysis by factor.

Missing data are common in surveys, for many legitimate reasons; however, it should be determined whether data is missing at random or whether some respondents have more missing data than others, ether on the whole or for only certain questions. Although there was some missing data for all questions (items), 498 respondents had no missing values for the entire set of 24 questions. There were many students who didn't answer each question (n = 317), but the total amount of missing data was not considered to be problematic. However, there were 100 people who didn't provide a valid answer for all of the questions. If the missing data here is replaced with the mean value of that variable, it could be problematic; therefore, a decision was made to exclude cases list-wise, which meant using only cases with valid values for all variables in the factor analysis. Even with the omission of cases with incomplete data, a sufficient number of cases (N = 498) remained to conduct a satisfactory factor analysis.

Items were submitted for principal components factor analysis to reduce the number of variables to a smaller set. This operation can identify an underlying, not observable construct that is represented by a set of attitude items and can simplify the description of the survey results with more reliable measures of the factor.

Principal components analysis with varimax rotation method, which maximizes the explained variance, was performed on all 24 items to generate orthogonal factors. Since Kaiser-Meyer-Olkin measure of sampling adequacy was found to be 0.73, we can comfortably proceed with the factor analysis. Factors with eigenvalues greater than 1.0 were retained for subsequent analyses, yielding eight factors to be extracted. These eight factors accounted for 64% of the variance. Eight extracted Factors were displayed in Table 2.

There were four items which loaded highly on the first factor. This factor (Factor 1) is described as measuring the confidence in students mathematics abilities. Four items loaded highly on the second factor (Factor 2) which appears to measure the confidence in students science abilities. Another four items loaded highly on the third factor (Factor 3) which is described as measuring the students' perceived utility of science. Four other items loaded highly on the forth factor (Factor 4) which appears to measure the students' perceived utility of mathematics. These four factors show the student attitudes distinctly oriented with subject matter.

Two other items which loaded highly on the fifth factor (Factor 5) are described as measuring the perception of the female role in mathematics and science. Another two items loaded highly on the sixth factor (Factor 6) which appears to measure the perception of the male role in mathematics and science. These two factors show students' sex stereotyping in both mathematics and science. Two other items loaded highly on the seventh factor (Factor 7) which is described as measuring the students' anxiety to succeed on mathematics and science tests. Two other items loaded highly on the eighth factor (Factor 8) which appears to measure the students' intention or desire to study mathematics and science in college. These four factors show the student attitudes regardless of subject matter.

In the next stage of the analysis, regression factor scores on the above factors were examined as the dependent variable for Multivariate Analysis of Variance (MANOVA) by gender, school level, and tier. This is a case of a 2 x 3 x 3 factorial analysis; therefore, there are seven related hypotheses that we can test in this design.

Results

For Analysis by Item

Across the board there were gender differences (F = 14.81, p = .000), level differences (F = 4.19, p = .000), and subject differences (F = 21.58, p = .000). Whereas the significant subject differences were revealed in four pairs of items. Two of them favored mathematics rather than science: "I will use math/science as an adult" [F(1, 588) = 150.71, p < .05] and "It is important to know math/science to get a good job" [F(1, 595) = 157.88, p < .01]. The other two favored science rather than mathematics: "® Doing math/science often makes me nervous or upset" [F(1, 604) = 10.97, p < .01] and "® I often get scared when I open my math/science book and see a page of problems" [F(1, 594) = 7.15, p < .01]. It is, however, the interactions that are of most interest.

The results of the repeated measures MANOVA across the board and the repeated measures MANOVA for each pair of items are presented in Appendix A with related mean scores. The results, subjected to repeated measures MANOVA across the board, showed a significant four way interaction for Gender x Level x Tier x Subject for overall student attitudes toward mathematics and science (F = 1.89, p = .000). The results of repeated measures MANOVA for each pair of items indicated statistically significant four way interaction for Gender x Level x Tier x Subject on six pairs of items out of 11 possible pairs of items; "I am good at math/science" [F(4, 613) = 5.65, p < .01], "® I do not enjoy math/science" [F(4, 599) = 6.55, p < .01], "® Doing math/science often makes me nervous or upset" [F(4, 604) = 5.32, p < .01], "I am interested in a career in math/science" [F(4, 605) = 2.75, p < .05], "I will use math/science as an adult" [F(4, 588) = 2.43, p < .05], and "It is important to know math/science to get a good job" [F(4, 595) = 3.78, p < .01]. The three way interactions for Gender x Level x Tier approached significance on a student attitude "® I often get scared when I open my math/science book and see a page of problems" [F(4, 594) = 2.822, p < .05] with the significant main effect favoring science rather than mathematics. Furthermore, there was a significant three way interaction for Gender x Level x Subject on "Math/Science helps a person think logically" [F(2, 569) = 3.12, p < .05]. The significant two-way interactions for Gender x Level were revealed on three pairs of items; "® Boys are generally better at math/science than are girls" [F(2, 597) = 9.12, p < .01], "® Math/Science is more useful for girls than for boys" [F(2, 608) = 6.12, p < .01], and "® I am not interested in studying math/science in college" [F(2, 609) = 4.95, p < .01]. Although several simple main effects reached statistical significance , they are of little interest because these interaction effects are the most interesting of the results.

For Analysis by Factor

Across the board there were gender differences (F = 13.66, p = .000) and level differences (F = 6.06, p = .000); however, it is the interactions that are of most interest.

The results of MANOVA for all factors 1 through 8 and ANOVA for each factor are presented in Appendix B with related mean scores. The results, subjected to MANOVA for all factors 1 through 8, showed a significant three way interaction for Gender x Level x Tier for all factors 1 through 8 [F = 1.93, p = .001]. The results of ANOVA by each factor revealed significant three way interactions for Gender x Level x Tier on confidence in mathematics and science abilities; [F(4, 459) = 3.63, p < .01] and [F(4, 459) = 7.79, p < .01], respectively. In addition, the significant simple main effect of gender with boys higher than girls were detected for both confidence in mathematics and science abilities; [F(1, 459) = 20.74, p < .01] and [F(1, 459) = 4.01, p < .05], respectively. There were two way interactions for Gender x Level on perception of the female and the male role in math/science; [F(2, 459) = 6.83, p < .01] and [F(2, 459) = 8.18, p < .01], respectively. In addition, the significant simple main effect of gender with boys higher than girls were detected for perception of the female role in mathematics and science [F(1, 459) = 4.95, p < .05]. Conversely, girls scored significantly higher than boys for perception of the male role in mathematics and science [F(1, 459) = 68.16, p < .01]. There was a significant simple main effect of level with elementary school students scoring higher than both middle and high school on intention or desire to study mathematics and science in college [F(2, 459) = 5.46, p < .01]. Also, a significant simple main effect of gender with boys higher than girls was detected for anxiety to succeed on mathematics and science tests [F(1, 459) = 4.52, p < .05]. No significant differences and interaction existed in perceived utility of mathematics nor science.

Discussion

It appears in analyses both by items and by factors that, in general, boys have more favorable attitudes toward mathematics and science than do girls. This is consistent with the findings of Catsambis (1995); AAUW (1992); Czerniak & Chiarelott (1984); Kahle (1983); Kurth, (1987); Lowery, Bowyer, & Padillia, (1980); Simpson & Oliver (1985); Schibeci & Riley (1986); Mullis & Jenkins (1988); and Weinburgh (1995). Student attitudes toward mathematics and science, however, vary not only by gender, but by school level, subject area, and tier phase as well.

With regard to confidence in mathematics abilities (see Figure 1), there are strong gender differences which reveal that boys have more confidence in their mathematics abilities than girls. This tendency is constant among all tier phases throughout all school levels with only one exception: only girls in the tier III phase at the elementary school level have slightly higher confidence in their mathematics abilities than those of their male counterparts. This may be due to low confidence in mathematics abilities of elementary school boys who are in the tier III phase. At the elementary school level, whereas girls' confidence in their mathematics abilities is low and fluctuates less among all tier phases, boys' confidence varies dramatically by tier level--especially boys at the elementary school tier III level have significantly lower confidence than those of elementary boys in tier I and II phases; therefore, the pattern of gender difference reverse at the elementary school level in tier III phases. Furthermore, school level has a substantial effect on the students' confidence in their mathematics abilities. Middle school students are most likely to have confidence in their mathematics abilities, high school students are those who are least likely to have a confidence in their mathematics abilities, regardless of gender or tier phase. That is, both boys and girls in any tier phases tend to lose a confidence in their mathematics abilities as they move from middle to high school level with only one exception: only boys in tier III phase gain confidence in their mathematics abilities as they move from middle to high school level. In contrast, girls in tier III phase lose confidence in their mathematics abilities dramatically as they move from middle to high school level, and high school girls in tier III phase have the lowest level of confidence in their mathematics abilities among the entire population; thus, an opposite pattern exists between boys and girls in tier III phase when they move from middle to high school level. This is the reason why high school students in tier III show the greatest gender gap with boys who have much higher confidence in their mathematics abilities than their female counterparts.

Although gender has an effect on students' confidence in their science abilities as well as those of their confidence in mathematics, the gender inequalities for students' confidence are less in science than in mathematics. Because students' confidence in their science abilities vary so much by gender, school level, and tier phase, there is no particular pattern in the student confidence in science abilities. Significant gender differences can be observed for students at the elementary school tier III level and for high school students in the tier II level. In both cases, boys show much higher confidence in their science abilities than their female counterparts (see Figure 2).

Gender and school level have substantial effects on the sex stereotyping in mathematics and science. Boys, more than girls, believe that boys are better at mathematics and science than girls, regardless of school level. Although elementary school boys are most likely to believe that boys are better at mathematics and science than girls, they lose this perception steadily as they get older (see Figure 3). This decline of boys' sex stereotyping may be due to boys losing confidence in their mathematics and science abilities, especially in mathematics, as they get older. On the other hand, girls are least likely to believe this stereotype and this tendency remains stable throughout all school levels; therefore, gender gap in this sex stereotyping (with boys holding this stereotype more than girls) is greatest at the elementary school level, decreasing gradually from elementary to middle school level, and even more sharply from middle to high school level.

In contrast, gender differences in another type of sex stereotyping in mathematics and science show a totally opposite pattern by school level. Elementary school girls are most likely to believe that mathematics and science are more useful for girls than for boys; however, high school girls are least likely to believe so (see Figure 4). That is, girls hold this stereotype more strongly at the elementary school level and they lose this stereotype dramatically as they get older. This decline of girls' sex stereotyping may be due to girls placing themselves in more traditional roles as they get older. Oakes (1990) explains that girls expect a conflict between math/science and family later in life; therefore, they lose their perceptions of the usefulness of mathematics and science for themselves as they get older. On the other hand, boys are less likely to believe that mathematics and science are more useful for girls than for boys and such a tendency remains consistent throughout all school levels. Gender gap in this sex stereotyping, therefore, is greatest at elementary school level with girls exhibiting this stereotype more than boys. This gender gap, however, decreases sharply from elementary to middle school level. Even more, this gender gap is reversed when students reach the high school level with boys displaying this stereotype rather than girls. These findings point to prejudiced or preconceived notions which suggest that sex stereotyping in mathematics and science decline rather rapidly with age, and that boys and girls do not stereotype equally.

With regard to test anxiety, there are slight gender differences appear as to feelings of success on mathematics and science tests. The findings indicate that girls have slightly more anxiety about succeeding on mathematics and science tests than do boys.

School level has a substantial effect on students' intention to pursue mathematics and science in college. For both genders and among all tier phases, students tend to lose their desire to pursue further study of mathematics and science in college. These findings add to the existing literature which reports similar findings for school level differences in student attitudes; science attitudes deteriorate throughout the school years (Cannon & Simpson, 1985).

No substantial effect appears as to perceived utility of mathematics and science. Both girls and boys believe both subjects are important and will be useful to their careers. This does not support the finding of numerous researchers who found more boys than girls perceiving mathematics and science as useful to their future career goals (Kahle, 1984; AAUW, 1992; Lockheed et al., 1985; Oakes, 1990; Dossey, Mullis, Lindquist, & Chambers, 1988; Eccles, 1984; Eccles, Adler, & Meece, 1984; Grandy, 1987; Hilton & Berglund, 1974; and National Science Board, 1987). The systemic reform efforts of the school district in this study may explain the reason why there is little gender difference here in perceived utility of math/science that is opposed to the findings reported in the literature. This finding of perceived utility, together with those of other attitudes, can provide a very interesting and useful analysis. That is, both boys and girls believe mathematics and science are useful to their future career goals; however, they have different attitudes toward mathematics and science. Although girls recognize that they have to use these subjects in the future, they feel less confidence and less of a liking of mathematics and science than do boys. This phenomenon can be explained by distinguishing between emotional and realistic attitude toward mathematics and science. Whereas girls' realistic attitudes are positive and reflect the dominant self-efficacy ideology, their emotional attitudes are more pessimistic and reflect their limited confidence and liking.

When the subject areas are considered (mathematics and science), there are differences found between mathematics and science in the repeated measures analyses. Both boys and girls see mathematics rather than science as more relevant to their future, whereas they see mathematics rather than science as a subject which makes them more nervous, upset, and even scared. Girls more often tend to be subject to mathematics anxiety at high school level.

Conclusions and Implications

The ultimate goal of this study is to seek ways that students can become more effective learners. Teachers can use these findings to design instruction specifically tailored to the needs of their students.

The following tentative conclusions may best capture our current understanding of student attitudes toward mathematics and science in gender differences for systemic reform efforts. Wayne State University's Survey of Student Attitudes Toward Mathematics and Science provide appropriate psychometric evidence of overall reliability ($\alpha = .79$). The factor analysis identified the following eight underlying factors which were psychologically interpretable: confidence in mathematics abilities, confidence in science abilities, perceived utility of science, perceived utility of mathematics, perception of the female role in mathematics and science, perception of the male role in mathematics and science, anxiety to succeed on mathematics and science tests, and intention or desire to study mathematics and science in college. Furthermore, the findings of this study suggest that girls feel less confident than boys in their abilities to succeed in mathematics and science; moreover, both genders have less confidence in their mathematics abilities than those of science. Girls feel more anxiety about succeeding on mathematics and science tests than do boys. Girls see sex stereotyping in these subjects differently than boys; however, they see mathematics and science as relevant to their futures as well as boys do, although both genders believe that mathematics is more useful for their future than science. Furthermore, both boys and girls, as they get older, lose their desire to pursue these subjects in college.

Although there are no important gender differences in perceived math/science utility and though both boys and girls perceive utility of mathematics and science positively, girls express much less confidence in mathematics and science. Systemic reform efforts, therefore, should find a way of increasing girls' confidence in mathematics and science, particularly in mathematics where gender differences are greatest.

Interventions like the systemic reform initiative in mathematics and science to change girls' attitudes may increase their achievement and their willingness to pursue the opportunities which are now available. Of highest priority are continued and expanded efforts to monitor overall trends in the students—particularly in girls attitudes toward mathematics and science--and to translate these data into indicators that are useful and accessible to policy makers and educators.

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Appendix A : Results of Analysis by Item

Table A1

Repeated measures MANOVA of student attitude; "I am good at math/science."

Source	SS	df	MS	F ratio	
	Tests involving Between-Subjects Effect				
Gender (G)	11.43	1	11.43	17.35	**
Level (L)	16.34	2	8.17	12.40	**
Tier (T)	2.48	2	1.24	1.88	
G x L	6.10	2	3.05	4.63	*
G x T	0.45	2	0.22	0.34	
L x T	9.25	4	2.31	3.51	**
G x L x T	3.95	4	0.99	1.50	
Error	403.79	613	0.66		
	Tests involving "Subject Area" Within-Subjects Effect				
Subject Area (S)	0.73	1	0.73	1.33	
G x S	2.65	1	2.65	4.82	*
L x S	13.11	2	6.56	11.93	**
T x S	6.31	2	3.15	5.74	**
G x L x S	1.79	2	0.89	1.63	
G x T x S	2.40	2	1.20	2.19	
L x T x S	3.29	4	0.82	1.50	
G x L x T x S	12.42	4	3.11	5.65	**
Error	336.85	613	0.55		

Note. N = 631.

*p < .05. **p < .01.

Means Table

	Gender		Level			Tier		
	Boys	Girls	Elem.	Middle	High	I	II	III
Math	3.29	3.00	3.29	3.19	2.83	3.15	3.25	3.04
Science	3.13	3.02	3.20	2.88	3.14	3.22	2.96	3.07

		Tier I		Tier II		Tier III	
		Math	Science.	Math	Science	Math	science
Boys	Elem.	3.45	3.36	3.48	3.16	3.25	3.42
	Middle	3.51	3.23	3.29	2.79	3.09	2.65
	High	2.92	3.11	3.15	3.22	3.43	3.29
Girls	Elem.	3.21	3.55	3.33	2.96	3.13	2.92
	Middle	3.15	3.12	3.28	2.88	3.09	2.85
	High	2.65	2.83	2.82	2.76	2.20	3.40

Table A2

Repeated measures MANOVA of student attitude; "® I do not enjoy math/science."

Source	SS	df	MS	F ratio	
	Tests involving Between-Subjects Effect				
Gender (G)	3.84	1	3.84	3.49	
Level (L)	11.62	2	5.81	5.28	**
Tier (T)	0.58	2	0.29	0.26	
G x L	8.43	2	4.22	3.83	*
G x T	4.00	2	2.00	1.82	
L x T	9.26	4	2.31	2.10	
G x L x T	1.83	4	0.46	0.42	
Error	659.31	599	1.10		
	Tests involving "Subject Area" Within-Subjects Effect				
Subject Area (S)	0.22	1	0.22	0.32	
G x S	1.53	1	1.53	2.17	
L x S	6.52	2	3.26	4.62	*
T x S	8.66	2	4.33	6.14	**
G x L x S	1.58	2	0.79	1.22	
G x T x S	1.25	2	0.62	0.89	
L x T x S	15.22	4	3.80	5.40	**
G x L x T x S	18.46	4	4.61	6.55	**
Error	421.92	599	0.70		

Note. N = 617.

*p < .05. **p < .01.

Means Table

	Gender		Level			Tier		
	Boys	Girls	Elem.	Middle	High	I	II	III
Math	3.15	2.95	3.22	3.10	2.73	3.02	3.13	2.99
Science	3.08	2.98	3.10	2.91	3.07	3.13	2.86	3.08

		Tier I		Tier II		Tier III	
		Math	Science.	Math	Science	Math	Science
Boys	Elem.	3.17	3.26	3.50	2.77	3.11	3.51
	Middle	3.11	3.00	3.09	2.59	3.06	2.89
	High	2.89	2.75	3.15	3.23	3.14	3.29
Girls	Elem.	3.00	3.56	3.09	2.65	3.37	2.89
	Middle	3.22	3.21	3.00	3.10	3.14	2.73
	High	2.65	2.73	2.94	2.78	2.06	3.25

Note. High value indicates "positive" attitude.

Table A3

Repeated measures MANOVA of student attitude; "® Doing math/science often makes me nervous or upset."

Source	SS	df	MS	F ratio	
Tests involving Between-Subjects Effect					
Gender (G)	2.49	1	2.49	2.27	
Level (L)	0.14	2	0.07	0.06	
Tier (T)	1.32	2	0.66	0.60	
G x L	9.80	2	4.90	4.46	*
G x T	4.83	2	2.42	2.20	
L x T	14.69	4	3.67	3.34	*
G x L x T	4.04	4	1.01	0.92	
Error	663.34	604	1.10		
Tests involving "Subject Area" Within-Subjects Effect					
Subject Area (S)	7.12	1	7.12	10.97	**
G x S	1.28	1	1.28	1.97	
L x S	14.63	2	7.31	11.26	**
T x S	1.94	2	0.97	1.49	
G x L x S	0.45	2	0.23	0.35	
G x T x S	0.47	2	0.24	0.37	
L x T x S	5.39	4	1.35	2.07	
G x L x T x S	13.82	4	3.45	5.32	**
Error	392.36	604	0.65		

Note. N = 622.

*p < .05. **p < .01.

Means Table

	Gender		Level			Tier		
	Boys	Girls	Elem.	Middle	High	I	II	III
Math	3.01	2.83	2.89	3.05	2.76	2.97	2.93	2.87
Science	3.10	3.03	3.02	2.92	3.31	3.16	2.96	3.09

		Tier I		Tier II		Tier III	
		Math	Science.	Math	Science	Math	Science
Boys	Elem.	3.22	3.04	3.13	2.96	2.78	3.36
	Middle	3.13	3.15	2.79	2.67	3.06	2.68
	High	2.62	3.00	2.92	3.35	3.29	3.57
Girls	Elem.	2.97	3.34	2.68	2.76	2.78	2.69
	Middle	3.19	3.25	3.07	3.05	3.04	2.89
	High	2.53	3.02	2.92	3.05	2.27	3.47

Note. High value indicates "positive" attitude.

Table A4

Repeated measures MANOVA of student attitude; "Ⓡ I often get scared when I open my math/science book and see a page of problems."

Source	SS	df	MS	F ratio	
Tests involving Between-Subjects Effect					
Gender (G)	4.62	1	4.62	4.86	*
Level (L)	12.48	2	6.24	6.56	**
Tier (T)	2.99	2	1.50	1.57	
G x L	5.28	2	2.64	2.77	
G x T	4.69	2	2.34	2.47	
L x T	15.00	4	3.75	3.94	**
G x L x T	10.73	4	2.68	2.82	*
Error	564.85	594	0.95		
Tests involving "Subject Area" Within-Subjects Effect					
Subject Area (S)	3.45	1	3.45	7.15	**
G x S	1.01	1	1.01	2.08	
L x S	2.46	2	1.23	2.55	
T x S	1.04	2	0.52	1.08	
G x L x S	0.51	2	0.25	0.53	
G x T x S	1.65	2	0.82	1.71	
L x T x S	1.06	4	0.27	0.55	
G x L x T x S	3.00	4	0.75	1.55	
Error	286.90	594	0.48		

Note. N = 612.

*p < .05. **p < .01.

Means Table

	Gender		Level			Tier		
	Boys	Girls	Elem.	Middle	High	I	II	III
Math	3.22	2.99	2.95	3.17	3.18	3.13	3.20	3.01
Science	3.26	3.18	3.11	3.17	3.39	3.25	3.22	3.19

		Tier I		Tier II		Tier III	
		Math	Science.	Math	Science	Math	Science
Boys	Elem.	2.91	2.87	3.33	3.38	3.08	3.25
	Middle	3.46	3.45	3.17	3.04	2.94	3.03
	High	3.03	3.37	3.30	3.52	3.71	3.50
Girls	Elem.	2.96	3.19	2.71	2.83	2.78	3.08
	Middle	3.48	3.44	3.40	3.29	2.89	3.00
	High	2.94	3.29	3.30	3.35	2.75	3.31

Note. High value indicates "positive" attitude.

Table A5

Repeated measures MANOVA of student attitude; "I am interested in a career in math/science."

Source	SS	df	MS	F ratio	
	Tests involving Between-Subjects Effect				
Gender (G)	0.83	1	0.83	0.60	
Level (L)	0.87	2	0.43	0.31	
Tier (T)	0.06	2	0.03	0.02	
G x L	2.46	2	1.23	0.88	
G x T	0.72	2	0.36	0.26	
L x T	3.25	4	0.81	0.58	
G x L x T	17.07	4	4.27	3.06	*
Error	844.83	605	1.40		
	Tests involving "Subject Area" Within-Subjects Effect				
Subject Area (S)	0.39	1	0.39	0.50	
G x S	0.98	1	0.98	1.24	
L x S	6.16	2	3.08	3.92	*
T x S	6.46	2	3.23	4.11	*
G x L x S	0.31	2	0.15	0.20	
G x T x S	0.25	2	0.13	0.16	
L x T x S	1.79	4	0.45	0.57	
G x L x T x S	8.65	4	2.16	2.75	*
Error	475.65	605	0.79		

Note. N = 623.

*p < .05. **p < .01.

Means Table

	Gender		Level			Tier		
	Boys	Girls	Elem.	Middle	High	I	II	III
Math	2.47	2.36	2.53	2.39	2.27	2.39	2.52	2.34
Science	2.44	2.46	2.39	2.42	2.57	2.50	2.33	2.51

		Tier I		Tier II		Tier III	
		Math	Science.	Math	Science	Math	Science
Boys	Elem.	2.55	2.41	2.96	2.40	2.09	2.32
	Middle	2.38	2.57	2.38	2.04	2.56	2.44
	High	2.49	2.41	2.38	2.69	2.43	2.71
Girls	Elem.	2.52	2.72	2.35	2.09	2.73	2.43
	Middle	2.35	2.41	2.48	2.45	2.22	2.51
	High	2.06	2.40	2.46	2.35	2.00	2.67

Table A6

Repeated measures MANOVA of student attitude; "I will use math/science as an adult."

Source	SS	df	MS	F ratio	
Tests involving Between-Subjects Effect					
Gender (G)	4.65	1	4.65	5.49	*
Level (L)	0.36	2	0.18	0.22	
Tier (T)	0.38	2	0.19	0.22	
G x L	0.22	2	0.11	0.13	
G x T	0.54	2	0.27	0.32	
L x T	11.30	4	2.82	3.34	*
G x L x T	3.87	4	0.97	1.14	
Error	497.45	588	0.85		
Tests involving "Subject Area" Within-Subjects Effect					
Subject Area (S)	69.53	1	69.53	150.71	**
G x S	0.45	1	0.45	0.97	
L x S	5.42	2	2.71	5.87	**
T x S	0.06	2	0.03	0.07	
G x L x S	2.00	2	1.00	2.17	
G x T x S	0.35	2	0.18	0.38	
L x T x S	1.99	4	0.50	1.08	
G x L x T x S	4.48	4	1.12	2.43	*
Error	271.28	588	0.46		

Note. N = 606.

*p < .05. **p < .01.

Means Table

	Gender		Level			Tier		
	Boys	Girls	Elem.	Middle	High	I	II	III
Math	3.50	3.58	3.44	3.58	3.63	3.51	3.56	3.55
Science	2.97	3.11	3.10	2.97	3.08	3.03	3.06	3.05

		Tier I		Tier II		Tier III	
		Math	Science.	Math	Science	Math	Science
Boys	Elem.	3.27	2.86	3.48	3.16	3.34	3.14
	Middle	3.61	3.07	3.70	2.57	3.47	2.71
	High	3.46	2.92	3.35	2.92	3.79	3.14
Girls	Elem.	3.43	3.18	3.62	3.48	3.47	2.83
	Middle	3.61	3.06	3.58	3.09	3.60	3.19
	High	3.67	3.00	3.60	2.91	3.69	3.31

Table A7

Repeated measures MANOVA of student attitude; "It is important to know math/science to get a good job."

Source	SS	df	MS	F ratio
Tests involving Between-Subjects Effect				
Gender (G)	0.22	1	0.22	0.23
Level (L)	2.05	2	1.03	1.10
Tier (T)	0.69	2	0.34	0.37
G x L	0.63	2	0.32	0.34
G x T	3.84	2	1.92	2.05
L x T	2.91	4	0.73	0.78
G x L x T	3.21	4	0.80	0.86
Error	556.29	595	0.93	
Tests involving "Subject Area" Within-Subjects Effect				
Subject Area (S)	80.23	1	80.23	157.88 **
G x S	1.83	1	1.83	3.60
L x S	1.75	2	0.87	1.72
T x S	0.02	2	0.01	0.02
G x L x S	0.07	2	0.04	0.07
G x T x S	0.64	2	0.32	0.63
L x T x S	2.40	4	0.60	1.18
G x L x T x S	7.68	4	1.92	3.78 **
Error	302.37	595	0.51	

Note. N = 613.

*p < .05. **p < .01.

Means Table

	Gender		Level			Tier		
	Boys	Girls	Elem.	Middle	High	I	II	III
Math	3.44	3.57	3.51	3.50	3.53	3.54	3.48	3.51
Science	2.97	2.95	3.06	2.93	2.88	2.96	2.94	2.97

		Tier I		Tier II		Tier III	
		Math	Science.	Math	Science	Math	Science
Boys	Elem.	3.45	3.05	3.68	3.24	3.31	3.03
	Middle	3.51	3.14	3.46	2.71	3.26	2.89
	High	3.43	3.00	3.27	3.00	3.64	2.79
Girls	Elem.	3.64	3.04	3.29	3.14	3.67	2.92
	Middle	3.54	2.77	3.55	2.88	3.67	3.12
	High	3.61	2.84	3.51	2.57	3.53	3.07

Table A8

Repeated measures MANOVA of student attitude; "Math/Science helps a person think logically."

Source	SS	df	MS	F ratio
Tests involving Between-Subjects Effect				
Gender (G)	3.73	1	3.73	3.25
Level (L)	3.12	1	1.56	1.36
Tier (T)	0.13	2	0.07	0.06
G x L	3.71	2	1.86	1.62
G x T	0.17	2	0.09	0.08
L x T	5.05	4	1.26	1.10
G x L x T	1.78	4	0.45	0.39
Error	652.66	569	1.15	
Tests involving "Subject Area" Within-Subjects Effect				
Subject Area (S)	0.85	1	0.85	2.12
G x S	0.17	1	0.17	0.43
L x S	0.75	2	0.37	0.93
T x S	0.54	2	0.27	0.68
G x L x S	2.58	2	1.29	3.12 *
G x T x S	0.98	2	0.49	1.22
L x T x S	1.89	4	0.47	1.18
G x L x T x S	1.46	4	0.37	0.91
Error	228.61	569	0.40	

Note. N = 587.

*p < .05. **p < .01.

Means Table

	Gender		Level			Tier		
	Boys	Girls	Elem.	Middle	High	I	II	III
Math	3.22	3.15	3.23	3.10	3.22	3.18	3.20	3.17
Science	3.21	3.07	3.13	3.05	3.24	3.16	3.08	3.15

		Tier I		Tier II		Tier III	
		Math	Science.	Math	Science	Math	Science
Boys	Elem.	3.23	3.32	3.09	3.17	3.19	3.19
	Middle	3.41	3.11	3.10	3.00	3.03	3.00
	High	3.24	3.16	3.41	3.37	3.46	3.54
Girls	Elem.	3.29	3.29	3.38	2.76	3.25	3.08
	Middle	3.10	2.94	3.19	3.12	2.98	3.07
	High	2.88	3.10	3.08	3.11	3.17	3.08

Table A9

Repeated measures MANOVA of student attitude; "® Boys are generally better at math/science than are girls."

Source	SS	df	MS	F ratio
	Tests involving Between-Subjects Effect			
Gender (G)	116.29	1	116.29	102.01 **
Level (L)	10.61	2	5.30	4.65 *
Tier (T)	1.51	2	0.75	0.66
G x L	20.80	2	10.40	9.12 **
G x T	7.73	2	3.87	3.39 *
L x T	10.99	4	2.75	2.41 *
G x L x T	11.95	4	2.99	2.62 *
Error	680.55	597	1.14	
	Tests involving "Subject Area" Within-Subjects Effect			
Subject Area (S)	0.09	1	0.09	0.23
G x S	2.35	1	2.35	6.19 *
L x S	0.81	2	0.41	1.07
T x S	0.75	2	0.37	0.99
G x L x S	0.23	2	0.11	0.30
G x T x S	0.57	2	0.29	0.75
L x T x S	0.95	4	0.24	0.62
G x L x T x S	1.90	4	0.48	1.25
Error	226.65	597	0.38	

Note. _N_ = 615.

*_p_ < .05. **_p_ < .01.

Means Table

	Gender		Level			Tier		
	Boys	Girls	Elem.	Middle	High	I	II	III
Math	2.83	3.57	3.09	3.27	3.41	3.23	3.28	3.24
Science	2.95	3.50	3.10	3.33	3.37	3.26	3.21	3.29

		Tier I		Tier II		Tier III	
		Math	Science.	Math	Science	Math	Science
Boys	Elem.	2.39	2.65	2.83	2.65	2.47	2.62
	Middle	2.76	3.07	2.74	2.91	2.77	2.97
	High	2.83	2.78	3.07	3.00	3.57	3.79
Girls	Elem.	3.75	3.57	3.55	3.36	3.51	3.59
	Middle	3.72	3.70	3.67	3.60	3.51	3.49
	High	3.44	3.42	3.51	3.51	3.53	3.27

Note. High value indicates "positive" attitude.

Table A10

Repeated measures MANOVA of student attitude; "® Math/Science is more useful for girls than for boys."

Source	SS	df	MS	F ratio	
	Tests involving Between-Subjects Effect				
Gender (G)	14.16	1	14.16	13.07	**
Level (L)	22.65	2	11.32	10.45	**
Tier (T)	0.85	2	0.42	0.39	
G x L	13.27	2	6.64	6.12	**
G x T	10.06	2	5.03	4.64	*
L x T	14.98	4	3.75	3.46	**
G x L x T	1.77	4	0.44	0.41	
Error	658.81	608	1.08		
	Tests involving "Subject Area" Within-Subjects Effect				
Subject Area (S)	0.29	1	0.29	0.64	
G x S	0.10	1	0.10	0.22	
L x S	0.16	2	0.08	0.18	
T x S	0.04	2	0.02	0.04	
G x L x S	0.74	2	0.37	0.81	
G x T x S	1.47	2	0.74	1.61	
L x T x S	1.18	4	0.30	0.65	
G x L x T x S	1.93	4	0.48	1.05	
Error	278.63	608	0.46		

Note. N = 626.

*p < .05. **p < .01.

Means Table

	Gender		Level			Tier		
	Boys	Girls	Elem.	Middle	High	I	II	III
Math	3.42	3.23	3.13	3.35	3.51	3.34	3.28	3.32
Science	3.37	3.21	3.10	3.30	3.49	3.30	3.26	3.28

		Tier I		Tier II		Tier III	
		Math	Science.	Math	Science	Math	Science
Boys	Elem.	3.61	3.52	3.54	3.27	3.11	3.29
	Middle	3.67	3.63	3.57	3.35	3.14	2.97
	High	3.57	3.49	3.33	3.48	3.64	3.71
Girls	Elem.	2.72	2.90	2.80	2.84	3.08	2.92
	Middle	3.51	3.39	3.27	3.37	3.31	3.36
	High	3.24	3.14	3.29	3.39	3.73	3.53

Note. High value indicates "positive" attitude.

Table A11

Repeated measures MANOVA of student attitude; “Ⓡ I am not interested in studying math/science in college.”

Source	SS	df	MS	F ratio	
		Tests involving Between-Subjects Effect			
Gender (G)	0.91	1	0.91	0.72	
Level (L)	9.18	2	4.59	3.63	*
Tier (T)	1.44	2	0.72	0.57	
G x L	12.51	2	6.26	4.95	**
G x T	2.97	2	1.49	1.18	
L x T	7.52	4	1.88	1.49	
G x L x T	3.81	4	0.95	0.75	
Error	770.01	609	1.26		
		Tests involving “Subject Area” Within-Subjects Effect			
Subject Area (S)	1.98	1	1.98	2.39	
G x S	0.43	1	0.43	0.52	
L x S	0.16	2	0.08	0.10	
T x S	4.26	2	2.13	2.56	
G x L x S	6.10	2	3.05	3.67	*
G x T x S	0.01	2	0.00	0.00	
L x T x S	9.55	4	2.39	2.87	*
G x L x T x S	4.20	4	1.05	1.26	
Error	505.64	609	0.83		

Note. N = 627.

*p < .05. **p < .01.

Means Table

	Gender		Level			Tier		
	Boys	Girls	Elem.	Middle	High	I	II	III
Math	3.04	3.01	3.15	2.94	2.96	2.92	3.13	3.00
Science	3.01	2.88	3.00	2.83	2.98	2.96	2.84	2.99

		Tier I		Tier II		Tier III	
		Math	Science.	Math	Science	Math	Science
Boys	Elem.	2.83	3.30	3.36	2.92	3.09	3.31
	Middle	2.88	2.89	2.74	2.61	2.66	2.74
	High	2.92	2.59	3.15	3.04	3.50	3.29
Girls	Elem.	3.00	3.17	3.38	2.71	3.16	2.71
	Middle	3.01	2.91	3.14	2.98	3.07	2.82
	High	2.82	2.65	2.81	2.76	2.56	3.13

Note. High value indicates “positive” attitude.

Table A12

Repeated measures MANOVA of overall student attitude

Effect	Multivariate F	p value
Tests involving Between-Subjects Effect		
Gender (G)	14.81	.000
Level (L)	4.19	.000
Tier (T)	0.98	.481
G x L	2.97	.000
G x T	1.43	.092
L x T	1.82	.001
G x L x T	1.06	.362
Tests involving "Subject Area" Withlin-Subjects Effect		
Subject Area (S)	21.58	.000
G x S	2.82	.001
L x S	3.32	.000
T x S	1.47	.074
G x L x S	1.99	.004
G x T x S	0.90	.593
L x T x S	1.60	.008
G x L x T x S	1.89	.000

Note. $N = 483$.

Appendix B : Results of Analysis by Factor

Table B1

ANOVA for Factor 1—Confidence in mathematics abilities

Source	SS	df	MS	F ratio	
Gender (G)	18.21	1	18.21	20.74	**
Level (L)	16.81	2	8.40	9.57	**
Tier (T)	4.95	2	2.47	2.82	
G x L	7.21	2	3.60	4.10	*
G x T	1.29	2	0.65	0.74	
L x T	3.52	4	0.88	1.00	
G x L x T	12.74	4	3.19	3.63	**
Error	403.02	459	0.88		

Note. N = 477.

*$p < .05$. **$p < .01$.

Means Table

		Elementary	Middle	High	Total
Boys	Tier I	0.25	0.43	-0.24	0.23
	Tier II	0.53	0.29	0.19	
	Tier III	-0.07	0.18	0.42	
Girls	Tier I	-0.02	0.23	-0.70	-0.16
	Tier II	-0.05	0.16	-0.22	
	Tier III	0.08	-0.14	-1.07	
Total		0.11	0.14	-0.24	

Note. High value indicates high confidence in mathematics abilities.

Table B2

ANOVA for Factor 2—Confidence in science abilities

Source	SS	df	MS	F ratio	
Gender (G)	3.32	1	3.32	4.01	*
Level (L)	10.99	2	5.50	6.64	**
Tier (T)	7.83	2	3.92	4.73	**
G x L	5.63	2	2.82	3.40	*
G x T	2.67	2	1.33	1.61	
L x T	24.26	4	6.07	7.33	**
G x L x T	25.80	4	6.45	7.79	**
Error	379.86	459	0.83		

Note. N = 477.

*p < .05. **p < .01.

Means Table

		Elementary	Middle	High	Total
Boys	Tier I	0.07	0.05	-0.07	0.16
	Tier II	-0.24	-0.37	0.49	
	Tier III	1.02	-0.42	0.40	
Girls	Tier I	0.35	0.10	-0.29	-0.09
	Tier II	-0.47	-0.18	-0.14	
	Tier III	-0.41	-0.38	0.77	
Total		0.08	-0.23	0.25	

Tier I	Tier II	Tier III
0.06	-0.16	0.12

Note. High value indicates high confidence in science abilities.

Table B3

ANOVA for Factor 3—Perceived utility of science

Source	SS	df	MS	F ratio
Gender (G)	1.17	1	1.17	1.18
Level (L)	1.81	2	0.91	0.92
Tier (T)	0.38	2	0.19	0.19
G x L	2.35	2	1.17	1.19
G x T	0.51	2	0.25	0.26
L x T	7.42	4	1.85	1.88
G x L x T	3.38	4	0.85	0.85
Error	453.89	459	0.99	

Note. N = 477.

*p < .05. **p < .01.

Means Table

		Elementary	Middle	High	Total
Boys	Tier I	0.00	0.08	-0.06	-0.06
	Tier II	0.16	-0.50	-0.02	
	Tier III	-0.17	-0.19	0.10	
Girls	Tier I	0.29	-0.08	-0.16	0.05
	Tier II	0.25	0.05	-0.28	
	Tier III	-0.09	0.20	0.15	
Total		0.05	-0.03	-0.02	

Note. High value indicates high perceived utility of science.

Table B4

ANOVA for Factor 4—Perceived utility of mathematics

Source	SS	df	MS	F ratio
Gender (G)	0.04	1	0.04	0.04
Level (L)	0.29	2	0.14	0.15
Tier (T)	5.35	2	2.67	2.75
G x L	1.21	2	0.60	0.62
G x T	0.89	2	0.44	0.46
L x T	2.37	4	0.59	0.61
G x L x T	1.08	4	0.27	0.28
Error	446.24	459	0.97	

Note. N = 477.

*p < .05. **p < .01.

Means Table

		Elementary	Middle	High	Total
Boys	Tier I	-0.24	0.11	-0.06	0.00
	Tier II	-0.19	-0.09	-0.25	
	Tier III	0.22	0.18	0.10	
Girls	Tier I	-0.05	-0.21	0.09	0.01
	Tier II	0.03	0.07	-0.24	
	Tier III	0.22	-0.01	0.05	
Total		0.03	0.01	-0.03	

Note. High value indicates high perceived utility of mathematics.

Table B5

ANOVA for Factor 5—Perception of the female role in mathematics and science

Source	SS	df	MS	F ratio	
Gender (G)	4.46	1	4.46	4.95	*
Level (L)	28.46	2	14.23	15.79	**
Tier (T)	0.39	2	0.20	0.22	
G x L	12.31	2	6.15	6.83	**
G x T	2.62	2	1.31	1.45	
L x T	9.40	4	2.35	2.61	*
G x L x T	1.35	4	0.34	0.38	
Error	413.75	459	0.90		

Note. N = 477.

*p < .05. **p < .01.

Means Table

		Elementary	Middle	High	Total
Boys	Tier I	0.01	0.48	0.26	0.10
	Tier II	0.17	0.21	-0.12	
	Tier III	-0.24	0.08	0.24	
Girls	Tier I	-0.79	0.29	0.10	-0.09
	Tier II	-0.61	0.08	0.15	
	Tier III	-0.58	-0.06	0.67	
Total		-0.36	0.12	0.25	

Note. High value indicates less sex stereotyping.

Table B6

ANOVA for Factor 6—Perception of the male role in mathematics and science

Source	SS	df	MS	F ratio
Gender (G)	52.78	1	52.78	68.16 **
Level (L)	9.29	2	4.65	6.00 **
Tier (T)	0.15	2	0.78	0.10
G x L	12.66	2	6.33	8.18 **
G x T	4.45	2	2.22	2.87
L x T	1.93	4	0.48	0.62
G x L x T	5.38	4	1.35	1.74
Error	355.46	459	0.77	

Note. N = 477.

*p < .05. **p < .01.

Means Table

		Elementary	Middle	High	Total
Boys	Tier I	-0.89	-0.34	-0.40	-0.35
	Tier II	-0.66	-0.33	-0.06	
	Tier III	-0.76	-0.40	0.40	
Girls	Tier I	0.41	0.55	0.31	0.33
	Tier II	0.15	0.46	0.32	
	Tier III	0.34	0.32	0.01	
Total		-0.19	0.14	0.15	

Note. High value indicates less sex stereotyping.

Table B7

ANOVA for Factor 7—Anxiety to succeed on mathematics and science tests

Source	SS	df	MS	F ratio	
Gender (G)	4.43	1	4.43	4.52	*
Level (L)	4.42	2	2.21	2.25	
Tier (T)	2.68	2	1.34	1.37	
G x L	1.67	2	0.58	0.59	
G x T	0.88	2	0.44	0.45	
L x T	6.45	4	1.61	1.64	
G x L x T	1.04	4	0.26	0.26	
Error	450.22	459	0.98		

Note. N = 477.

*p < .05. **p < .01.

Means Table

		Elementary	Middle	High	Total
Boys	Tier I	0.07	-0.02	0.21	0.10
	Tier II	0.23	0.33	-0.03	
	Tier III	0.17	0.41	-0.29	
Girls	Tier I	-0.02	-0.16	-0.14	-0.09
	Tier II	0.24	-0.05	0.02	
	Tier III	-0.04	-0.08	-0.52	
Total		0.09	0.05	-0.18	

Note. High value indicates less anxiety to succeed on mathematics and science tests.

Table B8

ANOVA for Factor 8—Intention or desire to study mathematics and science in college

Source	SS	df	MS	F ratio	
Gender (G)	0.22	1	0.22	0.22	
Level (L)	10.80	2	5.40	5.46	**
Tier (T)	2.97	2	1.48	1.50	
G x L	2.16	2	1.08	1.09	
G x T	0.59	2	0.30	0.30	
L x T	1.87	4	0.47	0.47	
G x L x T	3.56	4	0.89	0.90	
Error	453.79	459	0.99		

Note. N = 477.

*p < .05. **p < .01.

Means Table

		Elementary	Middle	High	Total
Boys	Tier I	0.02	-0.33	-0.32	-0.01
	Tier II	0.38	-0.16	-0.10	
	Tier III	0.07	-0.14	0.13	
Girls	Tier I	-0.06	-0.11	-0.09	0.00
	Tier II	0.44	0.12	-0.27	
	Tier III	0.30	-0.02	-0.37	
Total		0.19	-0.06	-0.14	

Note. High value indicates more intention or desire to study mathematics and science in college.

Table B9

MANOVA for Across all Factors 1 though 8

Effect	Multivariate F	p-value
Gender (G)	13.66	.000
Level (L)	6.06	.000
Tier (T)	1.84	.023
G x L	3.41	.000
G x T	0.97	.487
L x T	2.01	.001
G x L x T	1.93	.001

Note. N = 477.

Table 1

Description of Variables Investigated in the Study

Variable	Variable descriptions and characteristics	
Gender	Coding:	1 = Boy; 2 = Girl
Level	Weighted scoring:	1 = Elementary school 2 = Middle school 3 = High school
Tier	Weighted scoring:	1 = Tier I 2 = Tier II 3 = Tier III
Attitude	Attitude toward Mathematics 11 items on mathematics attitude	Attitude toward Science 11 items on science attitude
	• I am good at math.	• I am good at science.
	• ® I do not enjoy math.	• ® I do not enjoy science.
	• ® Doing math often makes me nervous or upset.	• ® Doing science often makes me nervous or upset.
	• ® I often get scared when I open my math book and see a page of problems.	• ® I often get scared when I open my science book and see a page of problems.
	• I am interested in a career in math.	• I am interested in a career in science.
	• I will use math as an adult.	• I will use science as an adult.
	• It is important to know math to get a good job.	• It is important to know science to get a good job.
	• Math helps a person think logically.	• Science helps a person think logically.
	• ® Boys are generally better at math than are girls.	• ® Boys are generally better at science than are girls.
	• ® Math is more useful for girls than for boys.	• ® Science is more useful for girls than for boys.
	• ® I am not interested in studying math in college.	• ® I am not interested in studying science in college.
	Weighted scoring:	4 = strongly agree 3 = agree 2 = disagree 1 = strongly disagree
	(Negative items had weighted scoring reversed)	

Note. Items designed ® are scored in the reverse manner.

Table 2

Order (by size of loadings) in which Variables Contribute to Factors

Factors and its description	Items which loaded on the factor
Subject matter oriented attitudes	
Factor 1 :**Confidence in mathematics abilities** α = .727	I am good at math. ® Doing math often makes me nervous or upset. ® I do not enjoy math. ® I often get scared when I open my math book and see a page of problems.
Factor 2 :**Confidence in science abilities** α = .690	I am good at science. ® Doing science often makes me nervous or upset. ® I do not enjoy science. ® I often get scared when I open my science book and see a page of problems.
Factor 3 :**Perceived utility of science (Instrumental Process)** α = .625	I am interested in a career in science. It is important to know science to get a good job. I will use science as an adult. I am interested in a career in math.
Factor 4 : **Perceived utility of mathematics (Instrumental Process)** α = .690	It is important to know math to get a good job. I will use math as an adult. Math helps a person think logically. Science helps a person think logically.
Attitudes regardless subject matter	
Factor 5 :**Perception of the female role in mathematics and science** α = .602	® Math is more useful for girls than for boys. ® Science is more useful for girls than for boys.
Factor 6 :**Perception of the male role in mathematics and science** α = .727	® Boys are generally better at math than are girls. ® Boys are generally better at science than are girls.
Factor 7 :**Anxiety to succeed on mathematics and science tests.** α = .60	I don't worry about how well I will do on math tests. I don't worry about how well I will do on science tests.
Factor 8 :**Intention or desire to study mathematics and science in college** α = .363	® I am not interested in studying math in college. ® I am not interested in studying math in college.

Note. Items designed ® are scored in the reverse manner.

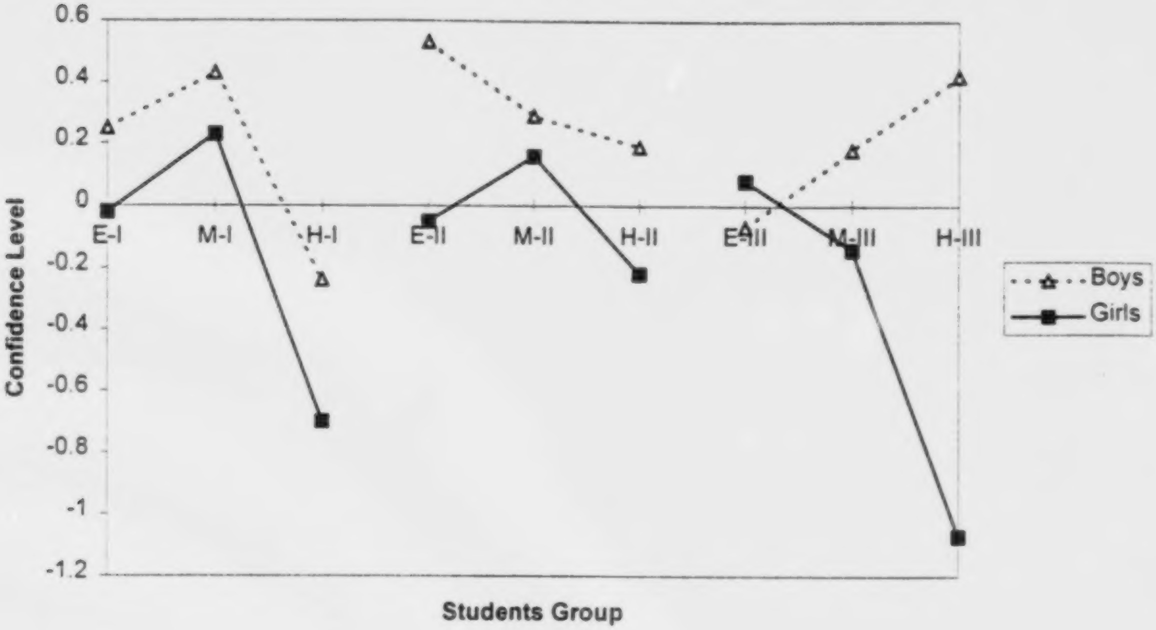

Figure 1.

Confidence in mathematics abilities.

E-I = students at elementary school tier I level. M-I = students at middle school tier I level. H-I = students at high school tier I level. E-II = students at elementary school tier II level. M-II = students at middle school tier II level. H-II = students at high school tier II level. E-III = students at elementary school tier III level. M-III = students at middle school tier III level. H-III = students at high school tier III level.

Confidence level is measured by regression-method factor scores.

Note. High value of confidence level indicates high confidence in mathematics abilities.

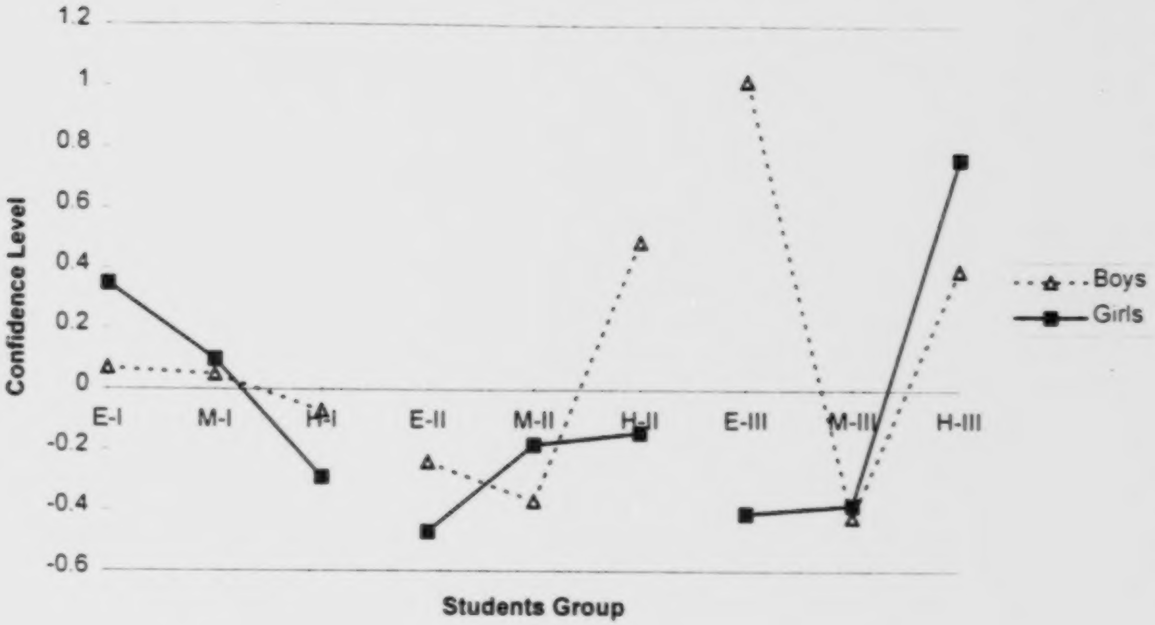

Figure 2.

Confidence in science abilities.

E-I = students at elementary school tier I level. M-I = students at middle school tier I level. H-I = students at high school tier I level. E-II = students at elementary school tier II level. M-II = students at middle school tier II level. H-II = students at high school tier II level. E-III = students at elementary school tier III level. M-III = students at middle school tier III level. H-III = students at high school tier III level.

Confidence level is measured by regression-method factor scores.

Note. High value of confidence level indicates high confidence in science abilities.

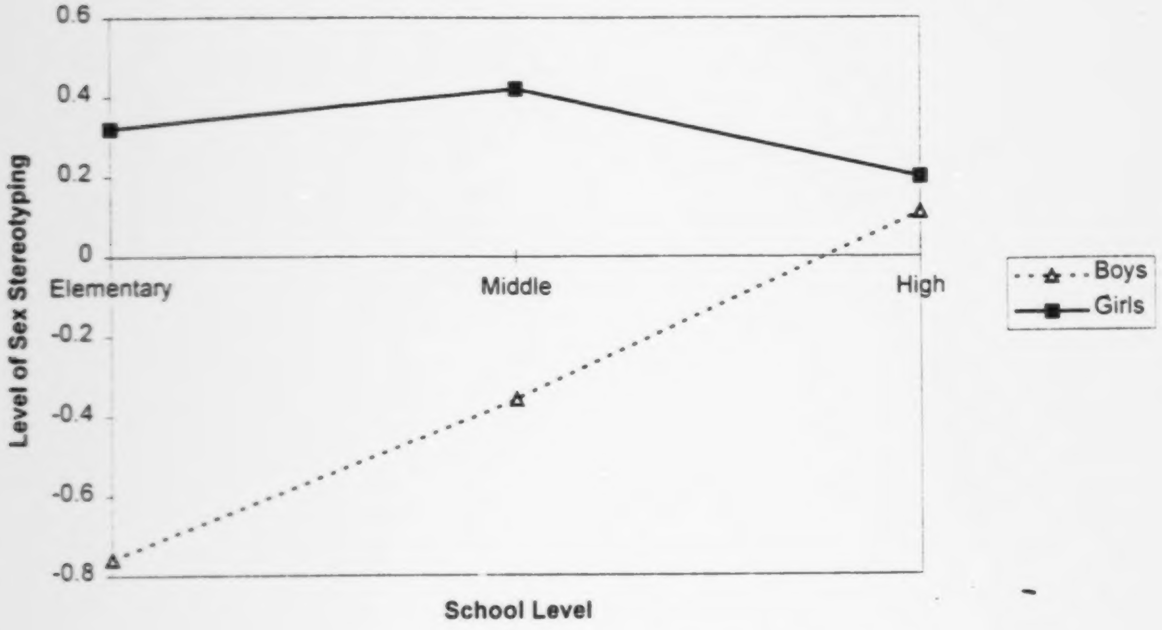

Figure 3.

Perception of the male role in mathematics and science.

Level of sex stereotyping is measured by regression-method factor scores.

Note. High value of sex stereotyping indicates less sex stereotyping.

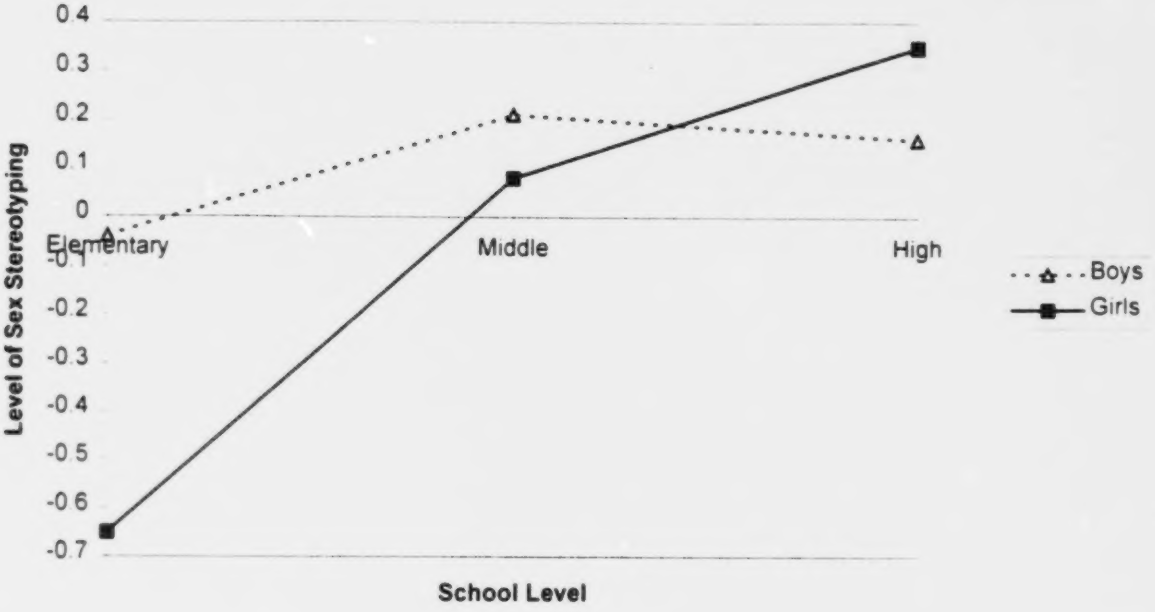

Figure 4.

Perception of the female role in mathematics and science.

Level of sex stereotyping is measured by regression-method factor scores.

Note. High value of sex stereotyping indicates less sex stereotyping.

TEXTBOOK ANALYSES: PRESERVICE ELEMENTARY TEACHERS' DEBUTS IN THE ROLE OF TEACHER AS RESEARCHER

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Purpose and Rationale

As in the past, a time came over the summer to begin to plan for the fall semester of teaching the elementary science teaching methods course that nearly 80 preservice teachers would enroll in. While sitting and contemplating the upcoming semester, reflecting back on past semesters, and striving for something better, an idea began to take shape. Both of the instructors, one a professor, the other a graduate student, have a long standing interest in the notion of teacher empowerment as a process and vehicle for social and political reform in education. Empowerment as we define it is a mind set that frees teachers and students to be powerful and decisive forces in shaping their own classrooms and beyond. Empowerment promotes shifts in power relationships within the school setting giving teachers and students voice in redefining and restructuring their schools, liberating them to be guided by their own visions. This notion is intricately related to what Stenhouse (1983) refers to as emancipation. In his writing he states, "The essence of emancipation as I conceive it is the intellectual, moral and spiritual autonomy which we recognise when we eschew paternalism and the role of authority and hold ourselves obliged to appeal to judgment" (Stenhouse, p. 163). It is a freeing from their "false consciousness," a state which Geuss (1981) describes as an acceptance of society's norms and living within them without questioning them (Geuss, p. 59). It is within this constraint of "false consciousness" that the true interests of the individual lie dormant, unexamined and thus become a restraining force, partially but not entirely self imposed. As instructors of preservice elementary teachers, it is this emancipation within ourselves and our students that we seek. We are well aware that such emancipation cannot be taught, but rather an environment must be created that nurtures this unshackling within ourselves and our preservice elementary teachers. We acknowledge that such a feat would be impossible within the sixteen week course that we teach, but ideally, as we instruct the first in a series of course work our preservice teachers take, we can at least be the initial impetus towards such emancipatory reconstructions about teaching and learning science.

It was with this ever present desire to foster and nurture a sense of empowerment in the future teachers with whom we interact that this first bud of an idea began to take shape and unfold. As in most preservice education programs (on average comprised of 86% females, according to Nelson, Weiss, & Capper, 1990), the preservice elementary teachers whom we serve are predominantly female. In dealing with such a student population, an awareness of women's ways of constructing knowledge becomes important for effective instruction to take place. It is the way in which women, though certainly not limited to women, come to know, through an immersion in the learning process and making the knowledge their own that such a transformation takes place (Maher, 1987). By utilizing this gender model advocated by Belenky, Clinchy, Goldberg, and Tarule (1986), we orchestrate experiences that our preservice elementary teachers explore which allows them to connect their cognitive knowledge to personal experience. Perhaps by utilizing such methodologies, we will begin them on their journey towards emancipation and empowerment.

Furthermore, as with most instructors, the notion of utilizing such a powerful strategy within a relevant context was immensely appealing. Our preservice teachers have come to see textbooks as a driving force in what they teach. This originates from their past indoctrination using textbooks as symbolic representations of the 'power of knowledge', 'the official version' of what is true, both in terms of knowledge and society's norms, values, and expectations (Scardina, 1972). In past courses, the preservice teachers have expressed an interest in finding out more about the texts; and it became evident in some of the things that they said that their understandings of the relationships between teaching and textbooks are fairly fixed. In one of our previous classes, as the preservice elementary teachers labored over writing lesson plans, one of our more outspoken preservice teachers raised her hand and asked quite pointedly, "Why do we spend so much time on this when the textbooks have the lesson plans already written out for us?" The notion of future teachers being as textbook dependent as many inservice teachers, was highly disconcerting. This becomes especially worrisome within science where numerous analyses have found textbooks to be lacking, and criticize them as doing little or nothing to promote critical thinking in science (Risner, Skeel and Nicholson, 1992). But it is one thing to present these findings about textbooks to our preservice teachers and another thing altogether to make this knowledge their own; to provide opportunities for our preservice teachers to discover this themselves. So the questions become--Where does knowledge originate? How do we know what we know?

With this philosophy in mind, the piece in the puzzle that remained missing was the how, the method for engaging preservice elementary teachers in discovering and exploring their own understandings of science textbooks. Much has been reported about the power of placing inservice teachers into the role of researchers as an agent that liberates and redefines the roles that they play within their classrooms and schools. As stated by Hopkins (1993, p. 35),

> The major consequence of doing this is that teachers take more control of their professional lives. Not content to be told what to do or being uncertain about what it is one is doing, teachers who engage in their own research are developing their professional judgment and are moving towards emancipation and autonomy.

It seemed a natural extension to look at how we could begin to coalesce the two, gently nudging preservice teachers into the role of researcher and doing so in a way that was relevant and meaningful to them while not overwhelming and stifling their initiatives. It was decided that we would use an inquiry/discovery approach in moving the preservice teachers towards becoming researchers, thus allowing them to engage in research in a very non-threatening environment. Utilizing such an approach, the preservice elementary teachers were unaware that the activity they were about to embark upon placed them in the role of researcher. Guidelines were open-ended and exploratory in nature, with the expectation that both instructors and preservice elementary teachers would be learning together as the project developed. The task of analyzing textbooks was scheduled into the syllabus. With the uneasiness of trying something for the first time, we began, not knowing exactly what to expect.

The following is a narrative, a partial reconstruction of the events, actions, thoughts and words of the participants from their own perspectives as the activity began.

The Beginning

Fall semester begins at this Midwestern university with three sections of "Elementary Science Teaching Methods" offered by two instructors who work collaboratively to teach the course. As the preservice elementary teachers enter the class for the first session, their trepidation is obvious. In part, it was the nervousness of beginning a new course and not yet knowing the expectations for that class, but there is something more insidious there. As the preservice elementary teachers begin by engaging in a discussion of their memories of science, it became clear that another fear was acting upon them; a fear that was deeply embedded in previous negative experiences with science and a dread that this course will not be any different for them. This anxiety is clearly voiced in many of the preservice elementary teachers' journal entries for the first week of class. About 52% of the 78 preservice elementary teachers directly expressed negative attitudes and feelings about science. In addition, another 10 to 15% made no indication in either direction as to their feelings or attitudes about science. The responses analyzed from journal entries indicating negative responses or feelings about science ranged from those who said that they never liked science because it was all memorization from the textbook to others who voiced insecurities about their abilities to do science. One preservice elementary teacher related that she had received low test scores on her IOWA Test of Basic Skills early on in her schooling and felt that based on this, teachers made the assumption that she couldn't do science and treated her accordingly. Consequently, she began to dislike science. She reflects in her journal, "I can't believe I let them tell me that I couldn't do science." A few preservice elementary teachers even stated that they hated science and nothing that we could do would change their minds. Some of the preservice elementary teachers discussed specific teachers that 'turned them off' from doing science. Many could not even remember elementary science. Out of the preservice elementary teachers that held more positive attitudes towards science, most discussed the fact that they had always been interested in science and some stated that their interest in science persevered despite their negative experiences in school.

Throughout the course, the preservice elementary teachers engage in discussions and lively, open discourse triggered by activities designed to explore the nature of science. These activities are engaged in with the aim that the preservice teachers will begin to redefine the way that they perceive science and the teaching of science. The activities included a mystery tube activity, several labs designed to explore the nature of science, articles to which the preservice teachers react that address the nature of science and projects such as experimental designs that engage the preservice elementary teachers in doing science like scientists. These activities are designed specifically to provoke and challenge preservice elementary teachers ways of thinking about science and science teaching. For example, two weeks following the mystery tube experience, Christy asked her instructor, "Are you ever going to show us what is inside the tube? Are we ever going to find out how it works?" It was at this point that the instructor responded by saying, "Did Mendel ever see a gene? Did Bohr ever see an atom? And the answer to your question is, no." To this Christy grinned. It is these continual probes and reflections about science and science teaching and learning that we wish to spark in this course.

Thus, in an attempt to combine the natural interest expressed by previous-classes of preservice teachers in science textbooks and provide another activity that might help them to question, reshape, and expand their images of science and science teaching, the new activity was introduced to the course. Again, the activity was designed specifically to thrust the preservice teachers into the role of teacher as researcher as they engaged in science textbook analysis, though the notion of doing research was never overtly part of the scenario. A spurious outcome was that they explored the nature of science and some of its underlying tenets while conducting the research. These tenets included science as a process; a way of knowing that is parsimonious, amoral, testable, objective, unified, developmental; and a human endeavor. While this was a desirous outcome, it was not the main thrust of the activity.

The Text Analysis Process

The preservice teachers were given a scenario about two thirds of the way into the semester which involved a final presentation to the school board reporting their team evaluations and recommendations for adoption of a new science textbook series. As a way of beginning, the preservice teachers were immersed as individuals with a probe into their notions of the nature of science teaching and an exploration of the roles of an elementary science teacher. Data collected at this point included written lists of descriptors of what an elementary science teacher does and drawings done by the individual teachers of what an elementary science teacher looks like. The preservice teachers then moved into small groups for discussion of the characteristics and roles of science teachers they had generated and the activity culminated in a whole group list. The groups then presented their lists to the class and the preservice elementary teachers noted during discussion, similarities and differences as well as frequency of their responses, thus giving them a view of how they and others perceived the roles of an elementary science teacher. Common descriptors across the three sections were coded and categorized by the instructors with the descriptors falling into one of four groups.

The first category encompassed affective qualities, those qualities which evoke a feeling or emotional response. Descriptors within this category included both positive and negative attributes such as: persistent, vivacious, caring, boring, weird (unable to relate to students), and an entertainer. A second category that surfaced embodied instructional roles, more directly related to what teachers do in the classroom. Examples of descriptors within this category included: performs assessments, opens children's minds, guides communication, creates a good learning environment, reinforces questioning, guides ideas, and motivates the class to take charge of learning. The third category that originated in the data focused more on science instructional roles. The roles included in this set of descriptors are items such as: explores systems and their senses so they can know the world around them, facilitates the student's exploration of scientific knowledge, clears up misconceptions about science, explores nature and explains it to students so that they can use and understand it as well as less positive descriptors like never uses manipulatives and tells you not to touch anything. The final category portrays the physical attributes of an elementary science teacher. Descriptors in this section included: women (11 out of 20), men (9 out of 20), wears goggles, old, middle aged, wears comfortable clothes, short, wears glasses, bald-headed, tall and thin, and wears a lab coat. Given these descriptors, there are noticeable stereotypical attributes of scientists (Finson, Beaver, and Crammond, 1995) in the list. While their lists were extensive, we were interested to find that in not one individual or group case did the role of researcher emerge across the three classes beginning this project. Also interesting, clearly reflected were their experience within the science methods course, witnessed in descriptors such as 'clears up misconceptions'.

It was also intriguing to note in their drawings of an elementary science teacher that approximately half of the drawings, 34 of 65 total, featured males in the role of science teacher and among their depictions, whether male or female, there were several similarities. Most of the pictures were fairly traditional in that the teacher wore a lab coat, was in a lab setting at the front of the room and was surrounded by science equipment, such as beakers, test tubes, and other apparatus. Many of the pictures were teacher-centered with the teacher performing some sort of demonstration to the students. Only 22 out of 65 drawings depicted students, with only six of those featuring children actively engaged. Only three of the pictures showed science outside of the classroom. This information served as a baseline for the instructors in interpreting how the preservice teachers viewed the role of an elementary science teacher and we were curious to know if their perceptions would change to include teacher as researcher as an important role after their course experiences and reflections. Therefore, upon completion of the text analysis, the preservice elementary teachers revisited their notions of roles of an elementary science teacher and in groups created a list of descriptors. While most of the roles descriptors remained relatively fixed, we were encouraged to find that 8 out of 15 groups listed researcher as a role of an elementary science teacher.

It was then time to get to the heart of the matter. The preservice elementary teachers self selected their textbook analysis teams and were given a set of student texts. Three of the texts series were utilized in school districts locally, and one, a more current edition, sent directly from the publisher. The textbooks analyzed were: Science (Silver, Burdett and Ginn, 1989), Discovery Science (Silver, Burdett and Ginn, 1995), Science for Life and Living (Biological Sciences Curriculum Study, 1992), and Science Turns Minds On (MacMillan/McGraw Hill,1995). The textbooks were selected to represent a variety of grade levels from kindergarten through 5th grade and the preservice teachers were given few initial guidelines as to how they should evaluate their texts. The following scenario was presented as an impetus for their explorations:

Figure 1
Textbook Selection Committee Scenario

Oct. 21, 1996

Dear Selection Committee,

Thank you for giving your time to select grade level science textbooks. As a team you will need to develop **a set of criteria** in which to evaluate the textbooks that you have been given. Keep in mind that the textbooks selected must be of highest quality and best fit the needs of a diverse student population (textbooks are costly). **One member of your team will document the process of how your team arrived at its criteria (documentation includes an ongoing description of your dialogue and decision making).**

You are only one team of the selection process. After you have developed your criteria you will meet with the other teams to negotiate a set of common criteria for all of you to use. Once the common criteria is settled upon, your team will then evaluate the text series you have been given. You will develop **analysis protocols** so that every one in your team will be analyzing in the same way. **Keep accurate records** of the text your group evaluates so comparisons across grade levels can be made.

The final report **should include the raw data, a description of how your team analyzed the data, your findings and recommendations.** Your team will present and defend the findings of the textbook evaluation before members of the School Board. The recommendations based upon your evaluation will be taken into consideration by the School Board for adoption.
The final report with be left with the members of the School Board for perusal after the formal presentation.

Thank you and good luck,

The School Board

The preservice elementary teachers began the actual text analysis by reflecting on what was important in teaching elementary science and from there, as a class, a series of criteria of the critical components that should be present in a science textbook were developed. Time was spent as a class defining and refining those criteria, until there was consensus on what each team would evaluate their texts. Throughout this process, the instructors struggled with how much to intervene, prompting a series of discussions to find ways to guide them in this process without *telling* them how to do it or impose our expectations of what a textbook analysis should look like. The preservice teachers worked both in a whole class setting and then within their groups to operationally define the criteria for comparison between the different texts. The core criteria were developed by consensus and despite the idiosyncratic differences in our approaches as well as the fact that these negotiations took place in three separate classes, the criteria were strikingly similar between the different sections. The overlapping criteria that emerged from the preservice elementary teachers included evidence of: hands on activities (open ended vs. closed, investigations vs. experiments), higher level and critical thinking questions, illustrations that were accurate, relevant and non-biased, age appropriateness, readability, good organization and layout, opportunities to extend ideas and activities, and content that addressed the National Science Education Standards (NRC, 1996). The similarities can be attributed to the common instruction that they received in their methods courses, which clearly informed their choice of criteria, but it must be also recognized that they share common experiences with textbooks as students and this in some ways guided their criteria selection. Slight variations came about as groups designed their own individual methodologies for assessing the texts based on these criteria using both qualitative and quantitative approaches.

The groups met both briefly in class and predominantly outside of class to evaluate their given texts. When asked to quantify the amount of time they spent on the text analyses, preservice elementary teachers reported anywhere from 10 to 18 hours on average Each group was required to keep a journal as documentation of the group process that they utilized while completing the textbook analysis, as well as continuing to individually keep a journal in which they reflected on their experiences. After a time that was negotiated between the preservice elementary teachers and the instructors, the preservice elementary teachers presented their findings to the class, utilizing charts, graphs, and other visual tools designed by each group to provide an in-depth portrait of the text they analyzed and their recommendations. Following the presentation of their findings, a final reflection questionnaire was given and follow up interviews were conducted. Throughout this process, the instructors also kept field notes on the project.

Findings, Constructions, and Interpretations

Upon completion of the text analysis and as the semester drew to a close, both instructors breathed a collective sigh of relief. The text analysis turned out to be quite an exhaustive process for both the instructors and the preservice elementary teachers. Several of the preservice elementary teachers indicated in their journals a sense of relief and accomplishment in completing the analyses. As we stood back and began the long process of sorting through the data, we surprised ourselves at the sheer amount of data that we had managed to accumulate. Separately, it hadn't appeared much, but collectively we realized that we had far more data than we had anticipated. We sorted through the data and contextually analyzed it for meaning, using an interpretive process (Gallagher, 1991). We individually coded the preservice elementary teacher's words and the events surrounding the textbook analysis drawing out interpretative themes through categorization. We became the instruments of analysis reconstructing themes and patterns as they emerged from the data, using the constant comparative method (Glaser and Strauss, 1967) of comparing data from within and across categories. We continued to analyze the categories until they were saturated. Primary data sources included: preservice elementary teacher journals, weekly instructor reflective sessions, random as well as purposefully sampled interviews, and artifacts including their individual assessments, drawings, descriptors of roles, final evaluations and the textbook analysis itself. Recognizing that any reconstruction is partial and positional, the instructors analyzed the data independently and then compared categories and negotiated themes for verification and triangulation. Both instructors intend on conducting a member check to add further validity to our findings when preservice elementary teachers return during the spring semester. From the data analysis, three major themes of the textbook research emerged.

Response to the Teaching Methodology

The first theme revolved around the open-ended methodology utilized by the instructors in the textbook research. Preservice elementary teachers indicated both in journals and verbally that the process was frustrating to them at times due to the lack of formal guidelines. Perhaps this is obvious, as stated by Chris in the early stages of the text analysis. He writes in his journal, "Worried about Textbook Analysis. I'm not sure about how and what. I have an idea, but I'm still not clear on how you want us to do it. I might just be blowing things out of proportion, but you know." This sentiment was voiced repeatedly with one preservice teacher finally saying to the instructor, quite exasperated, "I wish you would just tell us how to do this!!" She smiled in recognition of what she had said and then said, "But I guess you are not going to do that, are you?" It was not until the actual analyses were completed that the preservice elementary teachers began to voice some comfort and satisfaction in the process. This is illustrated by Heather as she writes in her journal, "I think that the most frustrating part of it [the textbook analysis] was how open-ended it was. You didn't tell us exactly what you wanted, and that was frustrating, but you made it like that purposely, right? I think this is good in a way because it let's all the evaluations be different and we get a wide range of ideas and see different ways of doing things." Another preservice elementary teacher, Holly, said, "I wasn't quite sure what you were looking for. But once we presented, I was comfortable. I felt we accomplished what was needed to evaluate a text." Many of the preservice elementary teachers echoed the reflections of Heather and Holly in their journal, but there were still some preservice elementary teachers that continued to be uncomfortable and dissatisfied with the process.

One preservice elementary teacher, Rachel, who was self-described as very concrete and sequential said this in her journal about the text analyses:

> While I feel that the project was worthwhile, I have a few concerns. Making the project very open-ended was a good way to allow us freedom to evaluate the textbooks as we saw necessary. However, I would have felt much more confident if at least some guidelines were presented. I don't think that the guidelines would be necessary for how to evaluate the textbooks, I agree that this needs to be as open as possible. Guidelines for the written and oral presentation would have been really helpful....The guidelines would not need to be specific, just enough to give us direction and to help us feel a little more secure in what we are doing.

It is clear that she is still not totally comfortable with the process and a large portion of her insecurity probably lies within her concern with her grades. She a high achieving student and always puts a great deal of effort into her work; pleasing and meeting the expectations of her instructor was still paramount. The text analysis was a graded assignment and as such, though we tried to leave the project as open as we possibly could, the fact that we as instructors still held the power of evaluation created some stress and discomfort among the preservice elementary teachers. This is a empowerment dilemma with which we continue to struggle.

Changing Portraits of Research

Beyond the methodologies utilized, this exploration was a way of knowing, an empowering experience through questioning and revisiting our own ideas as well as the preservice elementary teachers' ideas of research and the values associated with it. We found ourselves rethinking research as this study evolved. Jen a preservice teacher, said it best, " Research is science,...it is questioning everything and never taking an answer to be true...as research is always a way to find out something." Jen was on target. The root of the word *research*, search, means to look intently for something, but it also means looking around at things. So research is looking again and paying attention to things in systematic ways. Teacher research is a way of knowing, a way of finding out. The preservice teachers did not enter this course with the idea that they would be doing research. In fact, it was never addressed verbally. It did come out in conversations, journals, and interviews. We found patterns emerging from the data while preservice elementary teachers participated in and completed the text evaluation as well as other activities that related to their constructions of research. They began with images, we as instructors had not imagined, and left the course with self-reported changes in those images. Their ideas of research ranged from being surrounded by books in a library and drawing upon them and the expert knowledge they hold, to images of research as something they never thought they could or would be able to do. Midge portrays the first image vividly,

> Research is hard, going to the library and having to look things up, having to get in-depth, get right at what your looking at. When I think of research, I think of magazine articles, and research, like big thick books, and that's where you get it all from, the stacks.

Barb, another preservice teacher, connected this image and stated further that research was something she would never do. It was "beyond her reach and something that only professors do... not something that teachers do." A few preservice elementary teachers implicitly connected research to scientific skills and processes. One saw research as beginning with a question, collecting data, and analyzing data, working toward a goal.

It appears preservice elementary teachers hold a variety of myopic views about research as they enter the course, but as they reflected upon activities such as interviewing children and doing the text evaluation they verbalize changes in their views. They moved away from notions of research as a synthesis of knowledge found in books or something only scientists or professors do to something that they as teachers can do. Jay who held a "library image of research" revealed a change in perspective in the following:

> The textbook analysis doesn't match up with my previous ideas of research because I was doing it myself, I mean, I was taking this book and using my own criteria to judge it by and not necessarily what somebody else had set. All I had was this book and I had to decide on my own...well, as a group we decided on our own how it matched our criteria that we came up with ourselves so it is nothing like what I thought about research. When I researched [before] it was like you had a question set for you and it told you what to find and you had to go out and find it. And this way it was like...here's a book now, do it, which was actually better because this way I got to notice my own things instead of having to notice what someone else wants me to.

Debbie reflected upon her changing images in similar ways to Jay in the following:

> We had to stop and think about what would be relevant, what would be important, what would be necessary for a textbook. And we were the only resource that we had for that...so we had to decide that amongst ourselves, we couldn't go to a book that said, you

> know, this is what a textbook is supposed to be like, that's where we used ourselves as a resource.

Not all preservice elementary teachers found the activity one that prompted change in their notions of research. Jose saw the experience through different lenses, he stated that his background in science was strong and though the text analysis was beneficial it did not significantly reshape his ideas about research. Many of these reflections mirror preservice elementary teachers' past experiences. They recall passively doing "research papers." Now they are actively "doing research." The pedagogy and philosophy we use in our methods course and its activities are designed to challenge prior concepts of research, science, and science teaching using a conceptual change approach. Some preservice elementary teachers gain a new awareness and make new connections between research, science, and science teaching. This is summarized by Stefan, "It was not like any research that I have ever done, it was not big words, going to the library. Science to me is, well in this class, I found, is more hands on and the research was that."

For some students, there were new understandings about the dilemmas and limitations of research. While in the process of generating class criteria for evaluation across the textbooks, the preservice elementary teachers decided upon four main areas: pictures, activities, content, and organizational layout & terminology. These criteria were determined by stated operational definitions quantitatively which any individual in the team could use to get similar results. They recognized the need to use criteria that others could use for comparable, reliable results. For example, several groups decided to count the numbers of males versus females represented in pictures in the texts. Even though they found difficulty with defining other criteria in operational terms, they were not willing to give them up. It appears that the struggle to balance what they personally felt was important but not readily operationalized quantitatively (i.e. relevant activities connected to a child's experience, alternative extensions across subject areas, visually appealing-colorful and exciting, open to alternative assessments, etc.) fostered reflection about the objectivity vs. the subjectivity of science and research.

The following snapshots give insights into personal struggles and solutions to this dilemma. Chris wrote,

> This project helped me to see that we are instinctively subjective, but science needs to be more objective so that it has universal meaning. I struggled with this because I felt the subjective issues were important ones.

Chris viewed "objective" as quantifiable, but wasn't willing to give up the criteria whose data was not numerical. Clearly she found herself in the midst of the quantitative versus qualitative debate. Another student, Debbie reflected on the same issues noting that when she was doing picture counts of males vs. females in the text, she found that it wasn't quite as "black and white" as she thought. She cited the example that in the text they evaluated, the numbers of males vs. females was roughly equivalent, but that the majority of the females were not found until the last quarter of the book, which she noted, many teachers may never get to before the end of the semester. She found the only way to give a clear picture of the gender balance in the book was to include with the totals a descriptive section of data, presenting her findings she previously mentioned. Jen also found the the nonnumerical criteria challenging, recognizing that by its nature is one that could be open to multiple interpretations. She stated:

> When I was writing my individual accountability paper, I was surprised at how many real life applications I found. Really, many aspects of science can be related to children's lives in some way. It was interesting to hear how other people did their evaluations. Everyone approaches things in different ways. It's neat to see how one thing can be seen in so many different ways.

In the words of Cochran-Smith & Lytle (1993), "When teachers conduct research themselves, they make problematic what they think they know, what they see when they observe...and what they do with the disjunctures" (p.64). For our preservice elementary teachers, the "disjunctures" were finding ways to maintain within their research those criteria that were not easily quantifiable and more descriptive in nature. They find themselves struggling with the same issues researchers across the disciplines face. As with any research endeavor, the choices and the selection of important elements interface with the human factor to create a research design that is relevant and important to those doing it. In their defiance to not give up the less quantifiable criteria, the preservice teachers were thrust into the realm of qualitative research to seek resolution to some of the disjunctures in their textbook analysis.

As participants in this research we find ourselves guided by the words of Boomer (1987) who argues that "to learn deliberately is to research." Preservice elementary teachers here appear deliberate in thoughts about their own learning and the knowledge they possess. They clearly state what they know and how they came to know. It is a vital critical connection between the knower and the known. The connection becomes the initial step in conceptual change--facing your prior notions while restructuring new and more complete concepts. This is a novel way of knowing and according to Cochran-Smith and Lytle (1993), it is learning that does not necessarily involve new information but rather interprets information one already has--what she calls "REsearching" (Berthoff, 1987). Teacher research and research in teaching has the potential to challenge the predominant views of preservice education as a transmission model of knowledge by providing opportunities for the generation of knowledge through problematic inquiry within the various stages of becoming and being a teacher (Cochran-Smith and Lytle, 1993).

Importance of the Group Process

The use of group design for this project came as a result of having limited numbers of textbooks as well as a need to provide a supportive mechanism for the text evaluation project. This strategy brings up its own set of dilemmas and solutions by team members. The importance of the group process is described in part by false starts and unexpected turns in accomplishing their goals. Reconstructions here as elsewhere in this paper are tentative, unclosed and open to variables left unmentioned or unobserved. Fifteen teams were formed for the text evaluation and as part of the documentation, their decisions and decision making processes were included in the reports. Numerous data sources revealed that the preservice teachers felt that group dynamics were a central component in the development and conduct of the text analysis.

The actual process of analyzing the textbooks began as members of teams chose areas to evaluate determined by their preference and perceptions of the difficulty of the analysis (based on amount of time and effort). Equal work and effort were central to decision making. For instance, the following clips are representative of the preservice elementary teacher's documentations. Joshua described the process in these words, "We decided as a group who would do each part, giving everyone equal work loads. We decided to do a more elaborate check on one another as a change in our design." Alexandria documented the process in the following way, "First, we let whoever wanted to do an area do that area. On the basis of equity, we determined that by how much material needed to be covered. For example, the content seemed to be more material than the rest, so we had two people work on this area."

Other issues of the group process surfaced in the following reflections. For example, Chris wrote in her journal,

> I learned that working with a team takes time. Everyone must contribute in order for everything to come together. I think we came close to this. ... When working in a group, it is so important to have those operational definitions so that everyone is on the "same page" so to speak. Even though subjectivity is important to everyone, it is crucial to have objectivity when working in a group, otherwise there would be too many discrepancies.

Darcy found the negotiation of meaning challenging and exciting. She expressed that,

> The feature most important was realizing that this process was universal in meaning. This activity challenges the minds of an entire group, forcing them to come together as a unit. The one part of our group that I liked best was how each of us challenged each other's thoughts and made us back up our finding with an explanation. Terrific!!!

The documentation of the process revealed the issue of time being a critical component for the project by every group. The preservice teachers also reported that working toward consensus regarding the operational definitions of criteria was demanding, frustrating, and sometimes difficult to surmount. Continued communication among team members fostered a collaborative spirit whereby working definitions for data collection emerged.

There were groups in which the dynamics were not seen in a positive light. Some group assessments revealed tensions regarding individuals who were perceived by team members as not doing their jobs nor meeting their deadlines. In analyzing the dynamics within the two (out of a total of 15) groups that experienced difficulties, some patterns began to emerge. Field observations and informal conversations revealed that members within these two groups exhibited a tremendous diversity. In one group, there was an older married non-traditional student (returning to school after a hiatus), a male that described himself as a non-conformist (relishing in doing things that provoked response, like wearing his hair in pigtails and coming to class barefooted), one student who was openly very dedicated to his Fundamentalist Christian beliefs, a more traditional female student and a student that was experiencing personal problems and ended up not working with the group at all. The second group consisted of a single mother, a student who was also experiencing personal difficulties, a lone male that kept himself somewhat separated from the other group members, a female who was an only child and admitted to finding it difficult to work within a group setting, as well as two traditional female students.

A lack of communication seemed to be a pivotal contributor to tension within the groups. Debbie, a nontraditional and verbal member of the group voiced her concerns stating,

> They just didn't seem really interested in it...I don't think that they took it seriously enough and uh...I never did get it and I never did ask (she chuckles, ruefully). I didn't want to say what I was thinking, but the day before what really made me mad was the first time we met, Doug told me 3 or 4 times, now don't forget to be here tomorrow and he's telling me and then he doesn't even show up! And the next time I saw him, I said well, you weren't there, so this is what we told you to do, this is what you're doing and he said ok...no, oh God, I'm sorry...my car broke down or my house burned down...nothing, no explanation...just well, I knew you guys'd take care of it...that seemed to be the attitude of both of them.

Stephanie, another member of the same group wrote in her journal, "I don't feel that our group analyzed our series very closely as a group [sic]. The other groups seemed a lot more 'tight' with each other...Was it obvious in our presentation that none of us were very close?!" In the groups that experienced difficulties, this 'tightness' was lacking and they never really came together as a group, though each managed to produce an acceptable analysis of the text they were given. Contrast this to a comment made by Jason, a student in a group that functioned very effectively together:

> We didn't have a difficult time, we just jumped right into it and got started. (interviewer asked why he thought that this was) We all got along, we knew each other, and nobody was upset about what they got and we all wanted to work together. We trusted each other and were easy going with each other. I think everybody felt like they did an equal amount. It was hard to get time together...Jenna had the most difficult schedule so we worked around her schedule. We thought about not doing this as a group, but we decided to keep going.

The groups did have the opportunity to evaluate their team members a part of the process and in the 2 groups mentioned previously, the dissatisfaction with how they functioned was evidenced in their ratings of each other. Field observations and reflection of the instructors highlight factors in group dynamics which seemed to promote collaboration. These included "knowing one another" which refers to reciprocal understanding of what team members really think and believe, a personal connection between members that extends beyond the classroom, and a tolerance of self and others--all of which facilitate ongoing, open communication and a true collaboration. In the groups that experienced difficulty, the common thread between them was the inclusion of members, who due to personal difficulties, were rendered dysfunctional. It is clear that group members can overcome these difficulties if there is an awareness of the circumstances that impact the functioning of one within a group. For example, Sarah while discussing her frustrations with a group member that failed to complete her portion of the text analysis reflected,

> I realize Terri has personal problems, but I only know that because someone [else] told me. Otherwise, I might think that she did not care or was lazy. I wish she would at least say, look, I am having some problems, I can write my paper if someone else will type it, because I would have.

Summary and Implications

If inquiry is to be an integral part of the professional life span of elementary science teachers, we need to initiate them into the research process using social and organizational structures supportive of beginning teachers' learning and collaboration (Cochran-Smith and Lytle, 1993). The research originated with this notion as well as preservice teachers' requests to examine elementary science texts more closely. We provided the supportive social and organizational structure, and what unfolded was much more than the simple examination of science texts.

As this paper suggests, the preservice elementary science teachers found themselves examining their skills in working with others to determine what was important to them in elementary science textbooks. Reflections of group dynamics revealed notions of trust, "tightness," mutual commitment to a shared goal, and communication as essential elements to highly successful team projects. Other teams, recognized that some of their problems stemmed from a lack of one or more of these factors and voiced them. As Connor said, "The team provides support, but at the same time, pressure to do accurate work." In the role of researchers, the preservice elementary teachers felt the frustration of not knowing where to begin. They reflected upon the difficulty of using nonquantifiable criteria, including it despite the challenge it presented. Lastly, they felt a satisfaction and "confidence" in designing, conducting, and completing an endeavor that generated knowledge that was valuable to them. Every group reported a high degree of confidence in their textbook results, while including ways to improve the research. In this moment, they became reflective practitioners.

In addition, as researchers of our own practice, the exploration of how preservice elementary teachers interpret the events surrounding their research of elementary science textbooks was especially pertinent to us. Preservice elementary teachers were undergoing self critique regarding the assumptions they held of research, science and elementary science teaching. Their images of research, science, and the roles of elementary science teachers changed. Within a conceptual change framework, examining their early perceptions allowed them to challenge their assumptions and open themselves up for a broader vision of what they can be and do. This represents the initial stage in conceptual change whereby individuals recognize and challenge the inadequacy of their understandings. Though there was some resistance the teaching methodologies utilized in this process, overall the preservice teachers reported a sense of accomplishment and confidence in their products as well as a positive response to the teaching strategies utilized. The immersion into the text analysis project offered them opportunities to restructure their conceptual understandings of research, science, and science teaching by providing meaningful alternatives for understanding, as well as useful applications within the realm of education.

As preservice elementary science educators, we too, examined our own underlying assumptions of what preservice elementary education is and what it should be. Our discomfort came from resisting the traditional expectations, recognizing the potential of being blasted by student evaluations and accusations of not teaching them anything of value. It would have been easier to give them guidelines, but we persisted in being part of the change. Change is difficult, even for those willing to change because they face moment to moment decisions that influence their perceived roles and those of their students. This recognition made us tentative and uncomfortable, but at the same time was empowering, as we shed the "false consciousness" that limits how we perceive our roles and expectations. We had accepted the "given" that beginning preservice elementary teachers have so much to learn regarding science and science teaching that they don't have time to explore their chosen practice as a researcher. We challenged this "given" by embedding the researcher role within the structure of activities included in the science methods course. We found this invaluable. Preservice elementary teachers made the connection that what they were doing was research and were aware of the power within it. This has wider implications for reform and change in education. Before reform is systemic, it must take place on many fronts simultaneously. We, as university science educators represent only one front. Research in science teaching and learning should be informed by all those in the profession who work within these fronts. This includes inservice teachers, student teachers, preservice teachers, administrators, and university educators. When these professionals merge research findings they will produce a knowledge base that will be greater than anything we presently have regarding the preparation of science teachers and their continued progress within the profession.

In closing, in a publication of the American Association of Colleges for Teacher Education, *Knowledge Base for the Beginning Teachers,* Reynolds, (1989) said:

> Knowledgeable teachers are not technicians, but professionals worthy and able to make reflective decisions or judgments and plans based upon principled knowledge that is adapted to the particulars of their teaching situations, their students, their unique experiences, their special insights, self knowledge, values, and commitments (Cochran-Smith and Lytle, 1993, p. 41).

Reynolds portrays our view of science teacher education and the words implicitly suggest a journey that must start early within teacher preparation. Offering opportunities for preservice elementary science teachers to do research, within university teacher preparation programs, can provide them with a way of generating knowledge while fostering a confidence in knowing that is their own. Therefore, "REsearch" becomes the intellectual tool that informs perceptions of their roles in teaching science to children that resists the traditional viewpoints and embraces change through their own critical inquiries.

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ENHANCING UNDERGRADUATE SCIENCE INSTRUCTION THROUGH SCIENCE EDUCATION PARTNERSHIPS: THE G-STEP MODEL

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It is common practice, particularly in research-oriented higher education institutions, to employ graduate students as teaching assistants whose responsibilities involve instructing undergraduate science laboratory classes and facilitating discussion sections. Unfortunately, most of these teaching assistants (TAs) have little or no preparation for their roles as instructors and have varying levels of experience and background (Nyquist & Wulff, 1996). This lack of preparation may explain why many first year graduate students in the sciences are apprehensive about their initial teaching assignments (Allen & Rueter, 1990).

Pickering (1983) outlines both advantages and disadvantages of having TAs instruct undergraduate courses. Advantages include the ability to offer smaller class sizes and the realization that graduate TAs often identify better with undergraduate students, and therefore, serve as strong motivators. However, disadvantages often include the lack of competence due to inadequate teaching skills. In addition, most classes conducted by teaching assistants involve lecture-oriented instruction since the only teacher training comes from the modeling of their professors. Since many TAs will become professors, an effective and positive experience as a teaching assistant may help support these professors-in-training for their future roles.

To address these vital issues of TA training and instruction, manuals (McKeachie, 1986; Nyquist & Wulff, 1996) and training seminars (Gilreath & Slater, 1994; Lawrenz, Heller, Keith, & Heller, 1992) have been proposed and many institutions require that TAs attend some form of orientation program before taking positions as instructors. As shown in Table I, the nature of the help and support provided to teaching assistants in general varies widely depending on the university or academic department. This chart is derived from the literature relating to the training of teaching assistants in many disciplines, but will be discussed from the perspective of science education. The levels represent our view of the kind of increased support that should result in higher degrees of teaching competency.

Table 1
Typical levels of teaching assistant support and training derived from the literature

Level	Nature of Support and Training
1	The laissez-faire approach
2	Generic workshops for new teaching assistants
3	Discipline-specific workshops for new teaching assistants
4	Professor-specific mentoring (apprenticeships)
5	Partnerships with discipline-specific educators (such as science, mathematics, etc). for support and mentoring

The laissez-faire approach exists when there is no formal training offered by either the university or individual science departments. Students are forced to draw upon their previous experiences and the expectations and examples of colleagues. Unfortunately this common practice often results from the widespread belief that anyone can teach if they know the content or that pedagogy is not something that can be learned. The next level involves the delivery of generic workshops, usually for a few days at the beginning of each academic year. These workshops are often conducted by the university for all TAs, regardless of their future assignment or responsibilities. The third level, the discipline-specific workshop, is often designed by individual departments such as the biological or physical sciences. TAs are required to attend a series of workshops related to their own discipline focusing on specific procedures and expectations that should be followed during the year. These workshops may range from generic safety issues to delivering laboratory instruction. The fourth level, professor-specific mentoring is patterned after the apprenticeship model, where TAs work closely with an individual professor. At this level, professors become colleagues with their teaching assistants and help these young instructors become both professional researchers and effective teachers. The final level involves the formation of partnerships between science education students who have experience in science teaching methods. These science education students offer instructional support and mentoring to TAs during an academic year. This is the model we will present in this analysis.

Although the ideal TA program would incorporate a variety of assistance modes, little systematic research exists to show how TAs are best trained and which training schemes are most effective. In one study, Lawrenz, et al (1992) found that a discipline-specific physics training program resulted in high student satisfaction for sections of courses taught by trained teaching assistants. As part of the training, TAs attended instructional seminars focusing on cooperative learning techniques and constructivist approaches for teaching physical science. Although pedagocial issues were addressed, these TAs did not experience discipline-specific guidance or science education mentoring, nor did they have an opportunity to collaborate with science educators.

Nyquist, Abbott, Wulff, and Sprague (1991) described indicators of TA developmental stages in the process of moving from novice to professional levels, as a teacher or scholar. They named these stages the Senior Learner, Colleague-in-Training, and Junior Colleague. The ultimate goal is that each TA reach the Junior Colleague stage and demonstrate reflective thought about students and instruction, exhibit professional actions and attitudes toward students and engage in collegial discourse with authority. Nyquist and Wulff (1996) outlined ways of helping students reach the Junior Colleague stage by learning their specific discipline and engaging in professional dialogue and collaborative projects; however, methodological issues were not addressed. The formation of partnerships with science education students coupled with pedagogical seminars may provide the missing link when helping TAs move toward the goal of becoming junior colleagues.

The Graduate Science Teacher Enhancement Program (G-STEP) Model

Overview

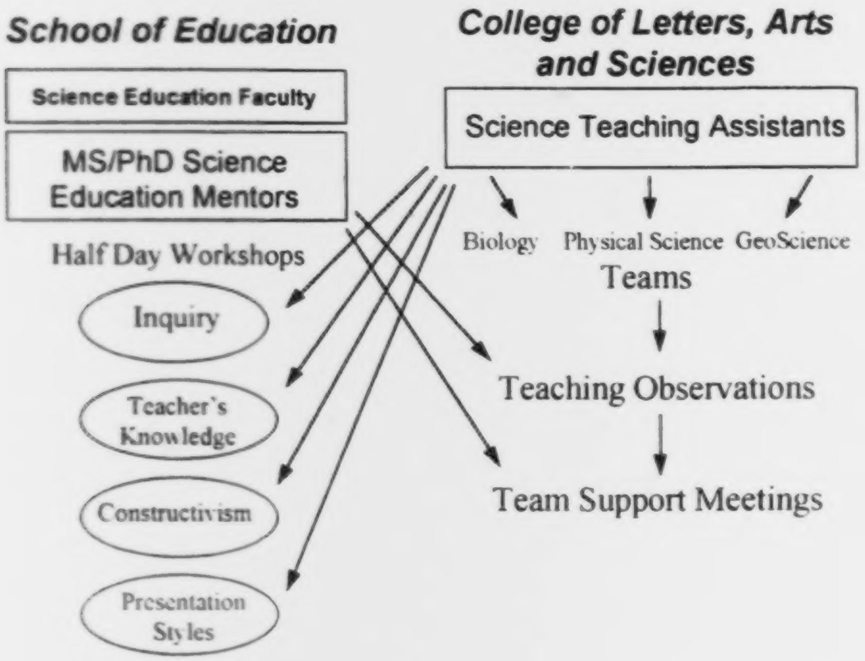
In recognition of the limitations found in those few teaching assistant training programs that have been reported, coupled with the fact that many TAs aspire to become effective instructors, we have designed, implemented, and evaluated an innovative model to assist TAs with the instructional aspects of their university experience. The G-STEP (Graduate Science Teaching Assistant Enhancement Program) is a unique project designed to provide formal opportunities to engage in professional experiences by linking science teaching assistants with science education majors.

The goals of G-STEP include:

1) Enhancing undergraduate instruction while helping science teaching assistants and science education graduate students develop as professionals;
2) Providing science education graduate students experience as mentors;
3) Introducing science TAs to current science education research and instructional methodology;
4) Creating collegial partnerships between science education students and teaching assistants from university science departments.

As illustrated in Figure 1, the G-STEP model is somewhat complex with participation from education faculty and students and teaching assistants from various science departments. The roles and responsibilities of each of the key people involved are discussed in the following sections.

Figure 1 The G-STEP model, an overview of the elements, participants and relationships


School of Education
Science Education Faculty
MS/PhD Science Education Mentors
Half Day Workshops
Inquiry
Teacher's Knowledge
Constructivism
Presentation Styles
College of Letters, Arts and Sciences
Science Teaching Assistants
Biology
Physical Science
GeoScience
Teams
Teaching Observations
Team Support Meetings

Half-day Workshops

The most formal element of the G-STEP model includes a series of half day workshops, held on Saturdays, conducted by the first author, a science education professor, who presented pedagogical implications of current science education research. Informed by both the needs expressed by TAs and current research-based trends in science education, we chose the themes of inquiry, teachers' knowledge, constructivism, and presentation skills for the four workshops.

The inquiry workshop focused on suggestions for enhancing laboratory teaching (McComas and Colburn, 1995). This workshop was most appropriate since the majority of the teaching assistants have responsibility for instruction in the laboratory environment, although most did not have role in selecting or designing the activities themselves. The workshop on the nature of teacher's knowledge (Shulman, 1986) was an introduction to the range of issues, experiences and information that an effective science instructor should have at his or her command coupled with assessment strategies. In the constructivism workshop, we discussed the range of possibilities for teaching models including the application of constructivism in instruction (Brooks & Brooks, 1993; Tobin, 1993). Finally, the presentation skills session, during interactive presentation by an outside specialist, provided opportunities for participants to examine their personal learning styles while designing instruction appropriate for the range of such styles (Gardner, 1993). Each of these workshops included cooperative learning activities, and the discussion of relevant journal articles associated with each topic. They provided opportunities for ongoing peer dialogue between science teaching assistants themselves and between science teaching assistants and science educators.

Science Teaching Assistants

Following the receipt of external funding to support the modest costs of G-STEP, and in cooperation with the university office of instructional enhancement, the program was designed and invitations were sent to teaching assistants in each of the science departments describing general goals and expectations of the program. Interested science teaching assistants completed an application which asked for a discussion of prior teaching experiences, reasons for wanting to participate G-STEP, and candidates' personal expectations for the program. Responses to the G-STEP application reflected a genuine need for enhanced teaching methods at the undergraduate level. For example, one science TA wrote, "Since my ultimate goal is to teach at the college level, I would like to do everything possible to enhance my skills as an instructor." Another student wrote, "I would like to take advantage of any worthwhile programs offered by the university that would allow me to become a more effective teacher." At the conclusion of the G-STEP program, science TAs received a small stipend and a certificate of participation. During its first year, G-STEP involved 15 teaching assistants from biology, chemistry, and geoscience departments. During the second year, G-STEP involved 16 teaching assistants from biology, physics, and the geosciences.

Science Education Graduate Students

The graduate science education students act as instructional mentors to the teaching assistants. Potential mentor participants are experienced classroom teachers in both elementary and secondary schools and who completed a formal graduate education course in advanced science teaching methods. A central feature of this advanced science teaching methods class included a series of activities in which students viewed videotaped presentations of science teachers and created assessment schemes based on what research recommends in support of high quality science instruction. In addition, several sessions were devoted to methods of clinical supervision. These two elements, rationale and research-based observation coupled with clinical supervision strategies helped to prepare science education majors to be effective mentors when interacting with science teaching assistants. The science education mentors received three units of tuition remission for their participation. In its first year, G-STEP involved five science education students and four science education mentors in its second year.

Partnerships: Linking Science Educators with Science Teaching Assistants

Partnerships between science education students and science TAs are mutually beneficial. Not only do TAs gain from the teaching experience and insights from the science education majors, but the science educators were able to apply what they learned in class and from their own professional experiences by performing authentic clinical supervision and providing peer support.

Teams were formed consisting of one science education student, and three to five science TAs. Teams are generally discipline-specific in reference to the science educator's expertise. This was helpful when discussing policies and expectations within specific departments. Each team member was assigned specific responsibilities during the year. Responsibilities of science education mentors and science teaching assistants varied slightly (see table 2).

Table 2.
The role and expectations of the science education mentors and the science teaching assistants participating in G-STEP.

Science Education Mentors:

1) Observe one class during the fall semester and two classes during the spring semester
2) Organize a pre-conference before each class visit
3) Plan a post-conference after each observation
4) Organize two informal seminars for team members
5) Communicate regularly with team members
6) Attend and participate in half-day G-STEP workshops

Science Teaching Assistants:

1) Work with your mentor/mentors to schedule class visits
2) Participate in pre-conference and post-conferences
3) Attend two informal seminars for team members
4) Communicate regularly with team members
5) Attend and participate in half-day G-STEP workshops

Mentoring Opportunities for Science Education Students

Throughout the academic year, partnerships between science educators and science teaching assistants were continually enhanced during the workshops, pre- conferences about classroom visits, observations, and post-conferences. Informal seminars also took place each semester over lunch, coffee, or in graduate student offices. The purpose of these sessions is to discuss reflections from the workshop series, discipline-specific problems in laboratory or discussion sessions, or to discuss teaching methodology not covered in the half day workshops.

Observation pre- and post- conferences were usually conducted individually by education mentors and science TAs. Occasionally, more than one mentor observed a lesson and provided additional feedback The purpose of the pre-conference was to discuss what the science TA would like the mentor to look for during the classroom obersvation Since science TAs have varying abilities, some participants needed different types of assistance. For example, if the TA has difficulty encouraging students to participate during post-lab discussions, the mentor may observe the population of students, types of questions being asked, and the seating arrangements of students to offer suggestions to help the TA remedy the problem. Suggestions were offered during post conferences.

Translating Knowledge Into Practice: An Evaluation of G-STEP

Qualitative survey data were collected from both the teaching assistants and science education mentors in an attempt to gauge the impact of the program, how G- STEP enhanced science instruction, and what areas of the model should be revised. Since surveys were anonymous, it is impossible to link application essays with the final survey results, but participants were asked to restate their initial goals and indicate the degree to which these goals were met during the program.

Each participant revealed that their goals were met to some degree and many participants volunteered that their personal expectations for the program were exceeded. Specific categories were generated from these surveys indicating that TAs found five workshop components most useful. These included discussions, reviews of teacher videos, discussion of learning styles and questioning strategies, and the creation of student-centered learning environments. During each workshop, time was allotted for TAs and Science Educators to discuss current topics and share problems. Teacher videos were utilized for viewing diverse instructional styles. An introduction to various learning styles and questioning strategies was the focus of two different sessions that included Gardner's theory of multiple intelligences and the practice of rephrasing convergent questions during lab instruction. Procedures for creating student-centered classrooms were salient features at each workshop and pre and post-conferences conducted by science education students.

The result of G-STEP workshops and mentoring varied in reference to how participants applied instructional information to their current teaching position. Three specific categories were generated from information provided by TAs commenting on the usefulness of the G-STEP experience. Each of these categories corresponded with useful workshop components discussed earlier. These categories included Learning Modalities, Student-Centered Labs, and Student Collaboration. Participants reported including visual aids, videos, and music in their lessons in ways not previously attempted. Student-centered labs entailed less "cook book" type instruction, more divergent questions with "wait time", and more active participation from students. Student collaboration was enhanced by encouraging cooperative groups and allowing students to choose partners for support.

Excerpts are included below indicating various methods learned and applied as a result of G-STEP.

TA #1: "I learned not to give students authoritative 'correct' answers and allow them to think more for themselves . . ."

TA #2: "Wait time -- it is not easy, but it really does work!"

TA #3: ". . . Using follow-up or closure at (the) end of (a) lab instead of just letting the lab end with no recap."

TA#4: ". . . I will also apply different methods of teaching to appeal to different methods of learning."

TA #5: "I've tried to give a little less cookbook-type instruction, as suggested. This seems to work well."

TA #6 "Active participation, asking questions, and turning some of the responsibility of learning on the student."

Science education students found that they were able to review many important strategies and methodologies for teaching science by attending G-STEP workshops. In addition, they indicated that the opportunity to gain mentoring experience and to work with science teachers at the undergraduate level enriched their development as a science educator.

Conclusions

Responses indicate that TAs learned to apply a more interactive style in their laboratory or discussion sections and generally broadened their repertoire beyond that typically seen in the undergraduate teaching arena. In addition, these science teaching assistants have developed a stronger background and rationale for applying various instructional strategies for teaching undergraduates. Science education students gained mentor experience which enhanced their professional development.

G-STEP is a model that capitalizes on blending the pedagogical strengths of science educators with the content expertise and desire to improve that often reside in science teaching assistants. This partnership has been shown to be an important and effective tool in the development of science educators as supportive mentors and teaching assistants as the professors of tomorrow while improving science instruction at the undergraduate level today.

Acknowledgments

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ENHANCING UNDERGRADUATE SCIENCE INSTRUCTION THROUGH SCIENCE EDUCATION PARTNERSHIPS: THE G-STEP MODEL

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Abstract

It is rare that university-based teaching assistants (TAs) attend professional development workshops designed to acquaint them with appropriate pedagogical models. Thus, these new instructors typically engage in ineffective instructional methods based on their experiences rather than on research-based rationales. The poor teaching at universities both by faculty and teaching assistants has been widely criticized in spite of some attempts to remedy the situation. This paper is the report of a low cost, innovative partnership model, G-STEP (Graduate Science Teaching Assistant Enhancement Program), designed to assist both TAs and science educators with personal professional growth and to enhance instruction delivered by science teaching assistants.

MR. REINKENS' NEIGHBORHOOD: CAN YOU SAY 'CONCEPTUAL CHANGE?'

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Introduction

Current reforms in science education focus on the need for students to conceptually understand science rather than knowing a breadth of science facts (AAAS, 1993; NRC, 1996). These recommendations are for students of all grade levels, from Kindergarten through high school and beyond. Understanding science necessitates conceptualizing content. To understand science conceptually means to know the ideas of science and the relationships between them. It includes knowledge of ways to use the ideas to explain and predict other natural phenomena, and ways to apply them to other events (NRC, 1996). Developing understanding presupposes that students are actively engaged with the ideas of science. The reforms suggest scientific understanding can be gained through inquiry instruction generated from student experiences.

According to Kelly's (1955) theory of personal constructs, thought processes are psychologically developed by experiences that serve to help the person anticipate future events. Prior experiences form background knowledge that people use to inform inferences made from future experiences. Thus, in any science classroom, it can be expected that children will have had experiences that helped them develop stable and functional constructs about the world. These constructs, or ideas, will influence interpretations made of explorations in science. Children's ideas are defined as experience-based explanations constructed by the learner to make a range of phenomena and objects intelligible (Wandersee, Mintzes, & Novak, 1994). Children's ideas are stable and resistant to change (Carey, 1985; Driver, Guesne, & Tiberghien; Novak, 1988; Stepans, Beiswinger, & Dyche, 1986). As long as the idea serves the learner in making sense of the world, it will remain the learner's theory (Driver, et al, 1985; Osborne & Freyburg, 1985). Children's ideas develop very early, and by the age of 5 or 6 children have evolved a robust and serviceable set of theories about their world (Carey 1985; Gardner, 1991; Piaget, 1929). The reforms have recommended conceptual understanding of science. However, student ideas will influence their understanding of science concepts.

Young children's ideas have been studied for many decades, with Piaget (1929) pioneering their study with the development and use of the clinical interview method. Science educators have adapted the clinical interview method to explore children's ideas in a plethora of science content areas (Osborne & Freyburg, 1985; Posner & Gertzog, 1982; Thier, 1967). Results of the study of children's ideas show that school children can proceed through their school careers and retain misconceptions about many science concepts (Anderson & Smith, 1986; Bar, 1989; Bishop & Anderson, 1990; Griminelli Tomasini, Gandolfi, & Pecordi Balandi, 1990; Hashweh, 1988; Hesse & Anderson, 1992; Nussbaum & Novak, 1976). The kinds of science instruction children are receiving do not seem to be effective in helping students change their conceptions toward the scientific convention. Students may be presented with evidence that their ideas are incongruent with an experiment or problem and reject the evidence, or reinterpret it differently within their own beliefs (Osborne & Freyburg, 1985). Even when students present what appear to be correct responses, they continue to harbor their own ideas (Driver, et al, 1985; Erlwanger, 1975; Herscovics, 1989; Osborne & Freyburg, 1985). Perhaps instruction has been ineffective in changing children's ideas because, though there have been many studies delineating the kinds of ideas children hold, there has been little impact of these ideas on classroom practice (Hewson, Bell, Griminelli Tomasini, Pecordi Balandi, Hennessey, & Zeitsman, 1995). The impact of children's ideas on classroom practice should be studied to see whether knowledge of students' ideas can influence teacher practice. Teachers with knowledge of student ideas may be influenced to develop instructional activities that would help students' ideas move toward scientific conceptions.

What is necessary to help children's ideas develop toward the scientific convention and the visions of the reforms? Posner, Strike, Hewson, and Gertzog (1982) theorize that students will remain committed to their ideas unless they are shown the necessity of their modification. The student must be dissatisfied with the existing conception, meaning the child's idea must no longer make sense to the child in explaining the concept. A new idea must be intelligible as well as plausible. Finally, the conception must be fruitful, and make sense in many situations. Strike and Posner (1992) reiterated that their theory of conceptual change is not a prescription for instruction, but only conditions necessary for ideas to change. A possible way for teachers to help students change ideas would be to scaffold them to a more accurate level of understanding (Rogoff, 1990; Vygotsky, 1991).

There are many factors that influence teaching elementary science. These factors are: (a) teacher perception of the importance of science in an elementary curriculum, (b) limited content knowledge held by elementary teachers, and (c) limited experience through formal coursework in participating in and presenting, hands-on science. Elementary teachers do not often see science as a pertinent topic, but rather as something to be taught only when other subjects have been covered (Abell & Roth, 1992; Schoeneberger &

Russell, 1986; Tilgner, 1990; Tobin, Briscoe & Holman, 1990). Administrators do not always see science as an important subject in elementary schools (Schoeneberger & Russell, 1986; Tilgner 1990). Seeing science as of little importance leads to less funding and support of elementary science (Stefanich, 1992). Because of lower funding, elementary teachers are likely to have inadequate equipment for teaching science. Inadequate equipment and limited time often inhibit teachers from providing in-depth instruction (Stefanich, 1992; Tilgner, 1990).

Elementary teachers lack confidence in their abilities to teach science due to weak content knowledge (Borko, 1993; Enochs & Riggs, 1990; Smith & Neale, 1989). Even elementary science enthusiasts who effectively teach concepts for which they have good background knowledge, have difficulty teaching other science concepts because of inadequate content knowledge (Abell & Roth, 1992). Lack of confidence and content knowledge is likely not unique to science, but in other curricular areas as well.

Elementary teachers often have not had experience participating in hands-on science, and therefore are unsure of how it should proceed in their own classrooms (Bybee, 1993). Typically elementary teachers take introductory science courses in their teacher preparation programs, yet those courses often do not suit their needs or interests (Tobias, 1992). Even elementary teachers with a positive attitude and interest in learning science may find college science coursework inhibiting to their learning (Dickinson & Flick, 1996). Given the numerous barriers to teaching science, compounded with lack of administrative support, it is impressive that many elementary teachers forge ahead and provide effective instruction.

Despite these constraints, elementary teachers are recommended to teach science for conceptual understanding (AAAS, 1993; NRC, 1996). The question is how we can best help elementary teachers provide the most effective instruction for their students, that would lead to better science achievement in the elementary grades. It is necessary to know what kinds of knowledge about teaching science to children would allow teachers to meet the science standards at the primary and elementary grade levels.

Method

Subjects

This case study investigated the efforts of one preservice elementary teacher in his efforts to effect conceptual change in his intern setting. The preservice teacher selected did not have as many constraints to his teaching of science as other elementary teachers may have. He had strong content knowledge, holding a bachelor's degree in electrical engineering, with six years of research experience. He was in a preservice teaching placement that valued and supported his strength in science. In addition, the subject had a strong interest in implementing conceptual change in his fifth-grade internship placement. He had a background in conceptual change research literature, and was using that education to design ways to know students' conceptions, strategies he could use to help change those ideas, and ways to assess conceptual change.

Kirk was enrolled in a Master's in Teaching program, and earned a Master's degree in teaching, as well as a K-8 initial teaching certificate. He was required to produce and defend a final research project on his teaching. He chose to see whether he could create a "Neighborhood of Science" in his internship position. "Neighborhood of

Science" referred to establishing a community of learners for which science was the focus of the classroom. Kirk sought to know how he could identify student conceptions, create activity and interactions that challenged their ideas, and evaluate student progress toward scientific conceptions within the neighborhood of science.

The class in which Kirk was placed for his internship was a fifth grade self-contained room in a middle class neighborhood. There were 23 students in the class, 11 girls, and 12 boys. The supervising teacher had 10 years of teaching experience, mostly at the fifth grade level. She had no expertise or interest in science. Her teaching of science was not observed as part of this project. However, Kirk described her as having a "well-oiled" class, with excellent classroom management skills and the ability to keep students actively engaged in the activities at hand or working on assignments with little distractions. Kirk also stated she was delighted to have a science person in her classroom. In fact, the teachers in her school decided to capitalize on Kirk's science background and interest, and requested he develop the Chemistry Unit for fifth grade. Kirk seized this opportunity as a way to allow him to develop and teach a unit he believed would influence conceptual change. This event allowed him to include in the unit the elements he believed to be important in knowing student conceptions, planning activities and interactions that would lead to conceptual change, and in assessing student ideas.

Data Collection

As Kirk engaged in his own investigation of his teaching, an outside researcher, not currently in connection with the university at which Kirk was enrolled, studied the methods developed and used by him. The data collection period took place over the 1995-1996 school year, as Kirk began planning to teach for conceptual change, and concluding with his assessment of his success. The data collection instruments included: (1) email correspondence tracking the development of the conceptual change chemistry unit, (2) interviews of the teacher's views of conceptual change and science teaching, (3) videotapes of six episodes of the teacher's science teaching, (4) a collection of journal reflections by the teacher, (5) copies of student journals and student work, (6) a copy of the teacher's report of his analysis of the effectiveness of his conceptual change strategy.

Data collection began with Kirk's planning for influencing conceptual change during his internship. Kirk contacted the researcher via electronic mail with a request for assistance in planning his conceptual change unit. Subsequent weekly email correspondence and journal reflections were shared between the researcher and teacher. In addition, four face-to-face interview meetings took place. Notes were made of interactions between the researcher and preservice teacher during the meetings. At the meetings Kirk was interviewed for his ideas about conceptual change and science teaching, and the progress he was making. Because the researcher provided Kirk with input in conceptual change teaching during his planning, this is a limitation of the study. Kirk may have designed his unit differently had he not made and maintained contact with the researcher.

Data Analysis—the researcher

Data analysis began with an examination of all data collected, using correspondence and teacher journal entries as the primary sources, and observations, interview, and student work as secondary sources. Triangulation of these sources provided protection against threats of validity. The researcher searched for patterns within the data using a constant comparative method (Taylor & Bogdan, 1984). The data was then categorized as patterns emerged. By a constant comparison of incidents in the data sources the researcher refined the concepts and explored their relationships to one another. The concepts were then integrated into a whole picture of the teacher's method of identifying student ideas. The researcher searched for evidence of (1) conceptual change teaching, (2) uncovering student ideas, (3) assessing student conceptual change.

As a final step in the data analysis the researcher engaged in discounting the data (Taylor & Bogdan, 1984). In the process of discounting, the data were looked at in the context of which they were collected. Data that was solicited and unsolicited were identified as such. Unsolicited responses from the teacher were viewed as valuable in determining how the teacher was identifying student ideas, or in leading to explaining any trouble with identifying ideas in a classroom setting. Next, the researcher's effects on the teacher were identified. It was presumed the researcher would have some effect on the teacher, since the teacher sought out the researcher with the purpose of receiving input on the design of his conceptual change teaching. The researcher's effect on the teacher was described. Finally, the researcher's comments and observations were noted as such in the body of the data collection, in particular field notes, as "O. C." The notation allowed the researcher to identify any personal observations, and when analyzing the data, to differentiate personal notes and inferences from actual observations.

Data Analysis—the preservice teacher

Kirk engaged in his own data analysis process. He kept his own journal of reflections on his teaching and its effectiveness. In his journal he recorded observations of his students, his thoughts while reading students' work, his thoughts while viewing videotapes of his teaching, and comments made by students to him as they worked. He also recorded his decision-making process for selecting activities, and daily and weekly reviews of entries that discussed project progress and notable data. These journal entries were shared with the researcher. Kirk used this data to assess student feelings about the "Neighborhood of Science," and changes in their ideas about chemistry concepts.

Data analysis included reviewing and coding all data as they were related to the research questions set out by the preservice teacher. Some data were used to address more than one research question. The research questions for the preservice teacher were:

1. How do my teaching methods contribute to my students' comfort levels in the neighborhood of science?
2. Which classroom activities are effective and contribute to the neighborhood of science?
3. How do my teaching methods contribute to achieving conceptual change?
4. How effective am I at identifying and addressing students' misconceptions?
5. What types of activities promote students to change their conceptions of a science topic?

Comparisons were made of the researcher's and teacher's analyses of the teacher's effectiveness at influencing conceptual change in students. Any discrepancies were analyzed for their differences.

Results

Results are described in three sections. First, a section discussing the researcher's observations of the teacher's conceptual change teaching procedures is included. Second, a description of the preservice teacher's analyses is discussed. Third, a comparison of the researcher and preservice teacher's results is reported.

Researcher Observations

Several patterns have emerged indicating the areas Kirk believed were important in influencing conceptual change in his students. First, Kirk was very concerned with student ideas about chemistry throughout the entire project. Concern and awareness of the importance of knowing student ideas began with his proposal for his Master's in Teaching research project. He wrote:

> They (teachers) need to be continuously aware of student conceptions, methods, and activities for addressing those conceptions, and recording student work and achievement. It is also the responsibility of the teacher to ensure that these phases of instruction are presented in a manner which is helpful in promoting the conditions identified as necessary for conceptual change by Posner, et al.

Kirk's concern with student ideas and wish to help students develop their ideas began with his planning of the unit, proceeded through the implementation of the unit, and continued during the assessment of students and his own success with the unit. Kirk used several methods to help him know his students' ideas. He used journal entries to encourage students to write about their individual ideas, class discussions to encourage exploration of ideas together, questioning techniques to help students focus on their ideas, and hands-on activities to help them confront their ideas.

However, Kirk was confronted with the difficulty of getting students who were accustomed to parroting back information to think about, and share their ideas, about what they were learning. He was frustrated at their unwillingness to discuss their ideas. This frustration was evident in Kirk's journal entry about his first day of teaching (Feb. 1):

> Getting their ideas. Yeah, right! That's just sarcasm. I'm not so sure if it is getting their ideas or observations in this case. I really emphasized I wanted their ideas while we were doing experiments. Most don't seem to be sure they have ideas of chemistry at all. They appear to be looking for someone to give them the answer so they can learn it?

Kirk was sometimes less than pleased with the journal responses. Though he promised students As on their journals if they discussed their ideas, only some students explained their ideas in writing. For students who did not describe their thinking, Kirk did not give As. Students received as low as D- on their journal entries. To encourage these students to share more about their own ideas, Kirk would ask questions such as "what do you think happened," and "why did you think that happened?" In later journal entries Kirk showed increased frustration at not getting students to describe their ideas. He wrote comments on student journal entries such as "you must tell me what you saw, " or "you must explain why you think it happened." Though the journal assignments were successful in getting some students to share their ideas in writing, they were not effective for all students.

Class discussions were another means for Kirk to identify student ideas. He presented topics for discussion, and asked students to respond with their ideas. During one such discussion, students described what they thought the difference was between physical and chemical change. Kirk was careful to accept all student ideas and wrote student responses on an overhead transparency. He did not reinforce "correct" ideas, nor reprimand those that were "incorrect." He hoped by accepting all ideas he would encourage more students to share their true conceptions. Following the collection of student ideas about physical and chemical change, students were asked to think of examples of where they had seen these changes, and how they could identify the type of change. Kirk believed students would better express their true ideas if they related them to what they encountered in their daily lives. Students came up with many examples, some of which were not scientifically accurate. Kirk used these ideas to plan activities to help students become better at identifying the differences, and in explaining why certain changes were chemical while others were physical.

Kirk planned daily explorations he hoped would encourage students to confront their ideas. Keeping with the spirit of the "neighborhood of science, usually these activities were collaborative investigations. While students were engaged in activities, Kirk would circulate the room, asking students to explain why they thought they were obtaining their results. This was in direct contrast to the supervising teacher, who often circulated the room while Kirk was teaching, but only asked students to explain what happened, not to offer explanations for why it happened. Kirk's requirements for students to justify their responses encouraged students to think about their data, and confront their ideas. It also enabled Kirk to note any erroneous ideas, and take them into account when planning future activities and interactions.

Preservice Teacher Observations

Kirk divided his analysis into areas addressing his research questions. He addressed his first two questions in the first section. He explained how his teaching methods contributed to student confidence and comfort in the neighborhood of science, and which classroom activities he found to be effective in creating a neighborhood of science. He then addressed research results for his final three questions. In this section he discussed how his teaching methods contributed to student conceptual change, his effectiveness at identifying and addressing students' conceptions, and the types of activities that promote students to change their conceptions.

Research Questions One and Two

Kirk found data describing the strategies he chose to develop a neighborhood of science, and student feelings and attitudes toward the unit. He also searched for data pointing to the effectiveness of his chosen strategies, and suggested alternatives that may be even better at contributing to a neighborhood of science.

Kirk believed data showed he had a strong desire to make students feel comfortable sharing their ideas. He consistently gave students the opportunity to share their ideas without judgment concerning the scientific accuracy of their statements. He strongly believed effective oral and written communication in the room was necessary to foster comfort and confidence in science. Kirk focused on getting students to phrase questions concerning the science content to allow them to develop their understandings. He shares one student's question: "How did they come up with the model [of the atom] since it can't be seen?"

He believed this willingness to phrase questions showed students' comfort in sharing ideas. He also believed this question would not be as readily asked in a classroom that used a didactic approach because students would focus more on presenting the answer they thought the teacher wanted. His focus for developing a comfortable and sharing "neighborhood of science" was open communication in the room. He noted that most students seemed comfortable and confident when sharing their descriptions of concepts and models.

Research Questions 3, 4 and 5.

Kirk had more difficulty searching the data for descriptions of conceptual change. To set up his conceptual change unit, he arranged activities to move from the observable concepts of chemical and physical change to abstract concepts like molecular and atomic structure. Students observed and recorded a variety of chemical reactions, and then shared their explanations for those reactions. Students were then introduced to the accepted models of chemical theory. Students were then given time to review the experiments and modify their ideas.

Kirk was unsure of his success at influencing conceptual change. He thought perhaps students were undergoing a development of a concept, rather than a change in conception. He believed they had such little background knowledge in chemistry that he was helping them build, rather than change, a concept. He found it difficult to assess the success of his conceptual change methods because he was not sure whether his methods were in fact, influencing conceptual change.

To improve on his methods at identifying student ideas and changing conceptions, he recommends using student journals in a different way. He thinks if they were more open-ended and required justifications for student predictions he would have a:

> better picture of what students think, and a better feel for their prior knowledge. By helping students improve their communication skills in science I can help them incorporate new concepts more readily.

Kirk also recommends two other methods that would further influence conceptual change. First, allowing students to do more of the experimentation on their own, rather than having many teacher demonstrations. While this would require specific lab training for students, the time involved would likely be well worthwhile. Second, having students make oral or video reports of their work would encourage them to share their ideas as a group, and to become better communicators of scientific ideas.

Comparison of Researcher and Teacher Analysis

How effective was the teacher at identifying student ideas, and assessing change in ideas? The researcher believed the preservice teacher was somewhat successful at identifying student ideas. When asked, he was unable to provide examples of specific misconceptions held by his students. The inability to furnish specific examples could indicate he was not wholly successful at eliciting, or recognizing, student ideas. However, he was able to share butcher paper lists of ideas students had shared during discussions, indicating he had collected these ideas. As a preservice teacher, Kirk did have several constraints. He was constrained by time, having only three weeks to identify ideas, teach to change those ideas, and then to assess whether he had been successful. It is unlikely students would undergo substantial conceptual change in such a time period. Students in this class were not accustomed to sharing their ideas. Their reluctance to share ideas created a stumbling block at the outset, making it more difficult for Kirk to influence conceptual change in a short time period. In addition, due to being in a classroom not his own, he was constrained by the amount of time he could spend on science each day.

Kirk himself, was confused as to whether he was focusing on changing conceptions, or on just helping students develop conceptions about chemistry. In his final report assessing his effectiveness Kirk wrote:

> I found that teaching for conceptual change is influenced by many things, including, but not limited to: the topic or concept under investigation, the students' ability to communicate their conceptions effectively, my own "on the spot" and journal response questioning skills, and my knowledge of the material.

Kirk spoke of being a little shaky in content knowledge regarding student ideas of chemical change. He felt he did not always know whether the examples given by the students were scientifically accurate. Upon reflection, he believed he could compensate for his perceived weakness in content knowledge by having students help him determine the scientifically appropriate answer.

He believed that creation of a "neighborhood of science" within which students are comfortable and willing to share ideas and inferences is central to changing student conceptions. Both the researcher and teacher agree that Kirk emphasized students sharing their ideas, and that helping students become effective communicators will provide much needed information for the teacher in identifying student ideas and planning activities to confront them, and in helping students become more comfortable in their own abilities to understand and explain scientific concepts.

Conclusions and Implications

Kirk, a preservice teacher with limited teaching experience, demonstrated an ability to develop an environment during which many students felt comfortable sharing their ideas. His success implies that given the drive and knowledge base, a relatively inexperienced teacher can create a classroom environment consistent with the reforms that allows students to share their ideas and engage in inquiry. It implies that preservice teachers can be aware of the importance of knowing student ideas, and that they can develop and carry out their own plans for influencing those ideas.

If a preservice teacher can invoke such an environment in a short period of time, experienced teachers with more background and knowledge of pedagogy and content, and perhaps pedagogical content knowledge (Shulman, 1986), may be even more successful in developing their own methods of identifying student ideas.

Kirk's awareness of children's ideas influenced his teaching in the areas of planning to identify those ideas, and planning to change those ideas. He sought out student ideas to inform his own teaching practice. He sought to use individual writing assignments and group discussions to identify and assess changes in ideas. He did not use individual interviews, nor pre- and post-tests to identify and assess those ideas. His choice to use methods that are different than those typically used by researchers implies that teachers may develop their own strategies that fit their students and teaching situations. Individual teachers may identify and address children's ideas in different ways.

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Further Development of a Comprehensive Undergraduate Science Education Program for Elementary and Middle School Teachers

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In the November 1996 issue of *NSTA Reports!*, under the headlines *Basic College Science Courses Filter Out Most Students, Says New NSF Report* , the NSTA quotes the recently released NSF report, *Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology* (NSF, 1996; NSTA, 1996). According to the NSTA article, the NSF report's primary recommendation is that, "college science and math programs should be refocused in order to better educate the 80 percent of the students who do not major in the science disciplines. All students should learn these subjects by direct experience with the method and processes of inquiry. Furthermore, any sustained national effort to improve science and math teaching eventually must address the quality of teacher education at the undergraduate level. Because few teachers, particularly those at the elementary level, experience any college science teaching that stresses the skills of inquiry and investigation, they simply never learn to use those methods in their teaching." The report also states that America's science, math, engineering, and technology faculty must actively engage their students preparing to be K-12 teachers (as well as others) by assisting them to "learn not only science facts, but also the methods and processes of research, what scientists and engineers do, how to make informed judgments about technical matters, and how to communicate and work in teams to solve complex problems." The NSF report further charges, that "while some institutions already are making the changes needed to help them meet that goal, most are not." (NSTA Reports, 1996, p. 11).

The traditional differences in philosophy and approaches to teaching and learning between colleges of education and sciences has been repeatedly cited as one of the major obstacles in providing appropriate teacher-training programs. In an effort to alleviate this problem, Wright State University (WSU) has fostered a unique environment through a collaboration between the

College of Science and Math and the College Education and Human Services (CEHS) by creating dual appointments for faculty within these two colleges. These faculty have the primary responsibility for the design, implementation and evaluation of science teacher education programs. The faculty, through their individual strengths and expertise in science disciplines and teacher education and a shared commitment to and vision of science teacher education, have formed a highly complementary and effective team.

In our planning to revitalize the teacher preparation program in science we followed the guiding principles set forth in *Revitalizing Teacher Preparation in Science: An Agenda for Action.* (Glass, Russell, and Anderson, 1993):

- "Every elementary-middle-secondary science education preservice student should experience the investigative nature of science." (p. 8). This translates into 1) "direct investigative activities; 2) at least one open-ended investigation carried out over an extended period of time; 3) given opportunities to collaborate with others -- do as scientists do -- and develop team work habits." (p. 9).
- "Every elementary-middle-secondary science education preservice student should have classroom and laboratory experiences that focus on relatively few, but powerful, topics in biology, chemistry, earth/space science, and physics." (p. 9).
- "All elementary-middle-secondary science education preservice students should understand the interrelatedness of science disciplines and the connections between science and other areas of knowledge." (p. 10). Our roles are then to assist students in understanding the connections among areas of science and to recognize that the efforts to learn how natural science, social science, mathematics, philosophy, and literature complement each other.
- "All elementary-middle-secondary science education preservice students should learn scientific content and thinking process in the context of contemporary, relevant, personal and societal issues and problems." (p. 11). This would be accomplished by designing courses that have application to the real world and by integrating scientific-technical and social issues.

- "All elementary-middle-secondary science education preservice students must have a sound understanding of the nature of learning and how it can be applied to the learning of science." (p. 11). Once again, courses and student learning experiences needed to include content and activities that are carefully selected to be appropriate and sequentially ordered to be cumulative and build over time using an exemplary hands-on, minds-on science curriculum.
- "All elementary-middle-secondary science education preservice students should have several intense and extended clinical teaching experiences at a variety of grade levels in diverse socio-economic and cultural settings." (p. 12). These experiences needed to be grounded in theory and pedagogical knowledge, and students must receive regular and systematic feedback from practicing master teachers, professors of science, and science educators. Courses and teaching must reflect appreciation for different learning styles, and modeling of higher-order questioning, use cooperative learning, and problem solving strategies. And another key element was good communication in that this type of endeavor requires intense and lively cooperation between faculties in education ant the arts and sciences.

The Science Education Program

The science teacher program incorporates the five major key elements of the NRC standards for science education (NRC, 1996), the NSTA standards for science preparation of elementary teachers (NSTA, 1992), and the Ohio Model (Ohio Department of Education, 1994). These are: Processes and Inquiry of Science (historical perspectives, the nature of science); Physical Sciences, Life and Earth Sciences, concepts and applications, articulated with broad themes and ideas, unifying concepts; STS perspectives, all taught within a constructivist learning environment, integrating pedagogy with conceptual understanding and content knowledge (See Figure 1). The program is founded on current content-specific science education research, science curricular guidelines as outlined by the national science standards, published curricular materials, and feedback from master teachers and partnership schools. The courses in the program are taught within a cooperative, constructivist, hands-on and minds-on environment. Furthermore, the courses integrate science content with content-specific pedagogy and employ authentic assessment strategies.

Figure 1. Five Common Curricular Strands Underlying the WSU Science Education Program

AAAS 2061 CHAPTERS	NRC STANDARDS	OHIO MODEL GOALS	NSTA STANDARDS	AGENDA PRINCIPLES
Nature of Science	Science as Inquiry	Nature of Science	#3	#1
Habits of Mind				
Historical Perspectives	History/Nature of Sci.			
Physical Setting	Physical Science	Physical Setting	#1 & #4	#2
	Earth/Space Science			
Living Environment	Life Science	Living Environment	#1 & #4	#2
Human Organism				
Common Themes	Unifying Concepts & Processes	Thematic Ideas	#1	#3
Society,	Personal/Social Perspectives	Societal Perspectives	#2 & #5	#4
Designed World	Science & Technology			
Nature of Technology				
Mathematical World				#6
Nature of Mathematics				

The specific goals of the elementary education science program are:

1) Students acquire an in-depth conceptual understanding of the fundamental science concepts in each content area through the inquiry process. This requires the successful application of these concepts in a wide variety of real-life situations which connect these concepts through unifying, interdisciplinary themes;

2) Students develop science process, problem-solving, and critical analysis skills utilized not only in the scientific process, but also in everyday life and decision-making;

3) Students develop appropriate attitudes toward science and science teaching, including the understanding of science as an ongoing process of questioning, designing experiments, implementing these experiments, and evaluating the results as opposed to a set of facts or procedures to be memorized;

4) Students become effective life-long learners and collaborative workers capable of independent and cooperative problem-solving, as well as, self-directed and motivated analysis, decision-making, and action;

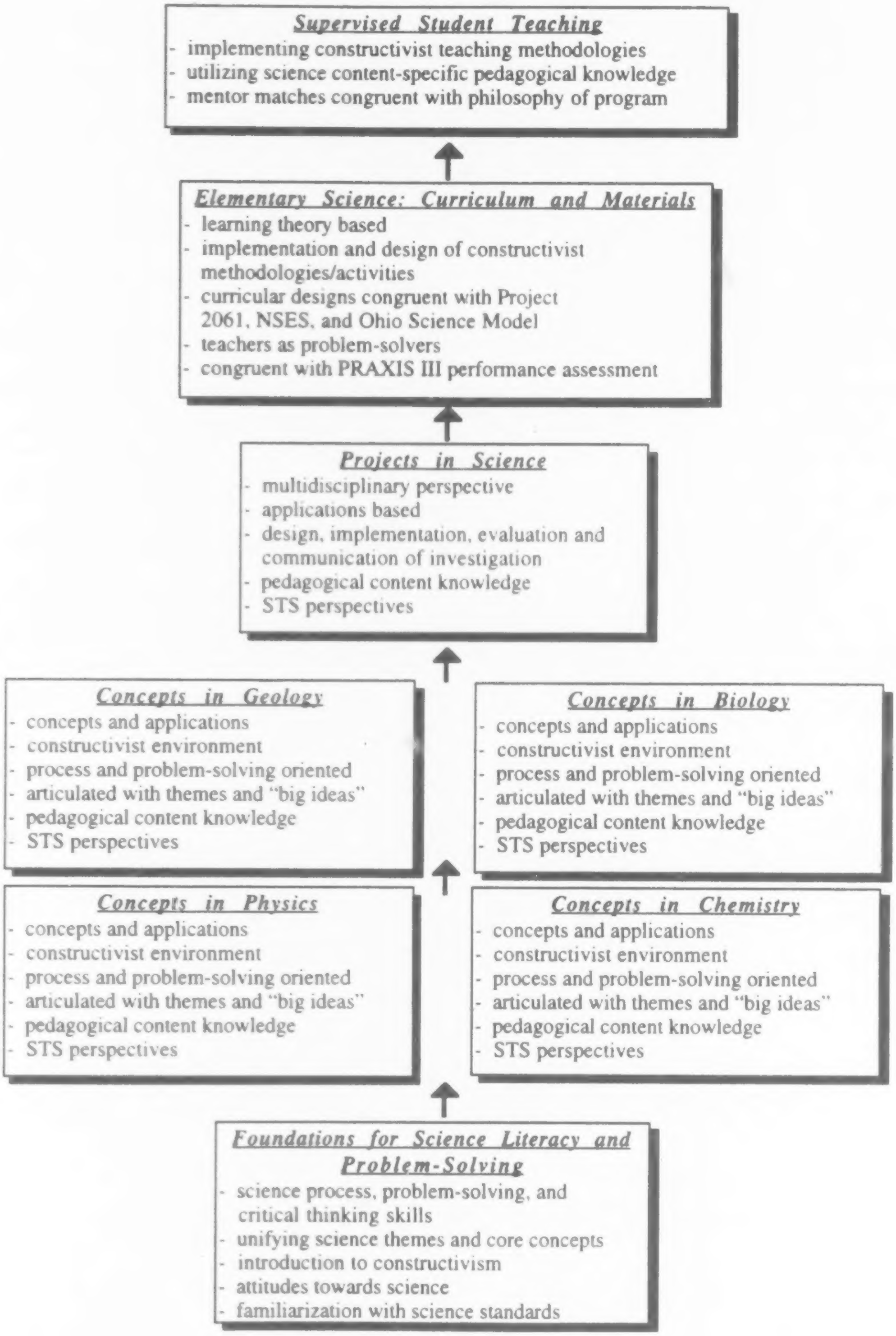
5) Students will be able to effectively implement constructivist teaching methodologies and utilize content-specific pedagogical knowledge to enable their future students to achieve scientific literacy.

All the courses were specifically designed emphasize science concepts and applications, constructivist pedagogy, pedagogical content knowledge, and science as a process. As such, the courses have a concise scope, in keeping with the philosophy of "less is more," are articulated with themes and "big ideas," include STS perspectives, and address student misconceptions. The courses are subsequently taught in a classroom setting of approximately 25 students who cooperatively work in small groups on hands-on inquiry activities.

The Foundation Course.

As shown in Figure 2, the introductory course is Foundations for Science Literacy and Problem-Solving, which provides the beginning student with a philosophical and experiential understanding of a constructivist, cooperative classroom environment. This understanding is acquired through introductory hands-on inquiry experiences within the context of fundamental, unifying, interdisciplinary science themes and core concepts such as systems and interactions, change and constancy, properties of matter. These experiences emphasize science as a process, problem-solving and critical analysis skills. Students are required to analyze their class experiences relative to their previous science experiences, the impending science courses of the

Figure 2. WSU Comprehensive K - 8 Preservice Science Education Program



Supervised Student Teaching
- implementing constructivist teaching methodologies
- utilizing science content-specific pedagogical knowledge
- mentor matches congruent with philosophy of program

Elementary Science: Curriculum and Materials
- learning theory based
- implementation and design of constructivist methodologies/activities
- curricular designs congruent with Project 2061, NSES, and Ohio Science Model
- teachers as problem-solvers
- congruent with PRAXIS III performance assessment

Projects in Science
- multidisciplinary perspective
- applications based
- design, implementation, evaluation and communication of investigation
- pedagogical content knowledge
- STS perspectives

Concepts in Geology
- concepts and applications
- constructivist environment
- process and problem-solving oriented
- articulated with themes and "big ideas"
- pedagogical content knowledge
- STS perspectives

Concepts in Biology
- concepts and applications
- constructivist environment
- process and problem-solving oriented
- articulated with themes and "big ideas"
- pedagogical content knowledge
- STS perspectives

Concepts in Physics
- concepts and applications
- constructivist environment
- process and problem-solving oriented
- articulated with themes and "big ideas"
- pedagogical content knowledge
- STS perspectives

Concepts in Chemistry
- concepts and applications
- constructivist environment
- process and problem-solving oriented
- articulated with themes and "big ideas"
- pedagogical content knowledge
- STS perspectives

Foundations for Science Literacy and Problem-Solving
- science process, problem-solving, and critical thinking skills
- unifying science themes and core concepts
- introduction to constructivism
- attitudes towards science
- familiarization with science standards

program, and their future science teaching practices. The goals of the course are to prepare the students for the subsequent science and education courses in the program by:

1) developing skills and thought processes necessary to become a complex thinker;

2) orienting students toward constructivist learning environment;

3) developing understanding of core science concepts such as mass, heat, temperature, etc. through unifying themes of properties and interactions of matter and systems, forms of energy, and change;

4) developing communication skills and the facility to utilize multiple representations;

5) familiarizing students with the national and state science standards;

6) developing appropriate student attitudes toward science and learning in general;

7) developing cooperative skills to become an effective collaborative worker;

8) developing skills and habits of mind that will enable the students to become effective life-long learners capable of independent, self-directed analysis, decision-making, and action.

This course is additionally the writing intensive course (as part of the WSU Writing Across the Curriculum initiative) for the science program. This affords the students the opportunity to express their views and attitudes toward science teaching and learning methods, as well as, to develop necessary critical writing skills. This course affords the science educators the opportunity to begin tracking the students in areas of attitudes toward science process, science learning, science teaching, as well as. their own science literacy. Each of these components is assessed throughout the program, beginning in this course.

Physics and Chemistry

Following the Foundations course, as illustrated in Figure 2, the students next take their physics and chemistry courses. Since these subjects are typically the subjects that students have had the least experience in, developing positive student attitudes is imperative. The integration of mathematics with these courses, although many times a source of trepidation for the students, allows the students to develop a further understanding of applications of mathematical skills within the context of a science investigation. These courses utilize the learning cycle in a constructivist way by providing a concrete science situation illustrating the science concepts first, then analyzing the "how do we know?, why do we believe. . ." component of inquiry, and finally investigating an application of the concepts in other situations. The students go through many learning cycles starting with concrete examples before they are expected to manipulate abstract ideas. This method affords opportunities to address student misconceptions and to allow the students to acquire a depth of conceptual understanding in such areas as motion, forces, and energy transfers.

These courses emphasize development of science process skills and problem-solving skills, as well as, conceptual depth. For instance, in the physics course, students utilize multiple representations of physical situations to aid in the abstract analysis of the concepts within these situations, and to aid with applications of the concepts in many different situations. The science, technology and society component of the course is incorporated through the many real-life applications of the science concepts that the students experience.

The students also have course projects in which they design, implement and assess elementary/middle level science activities. In their activity design, they not only emphasize correct science process and conceptual aspects, but also the constructivist and cooperative methods utilized in implementing the activity. The students facilitate their own activities for the class and the class, as a whole, helps in the assessment.

Biology and Geology

As illustrated in Figure 2, following the physical science courses, students enroll in their biology and geology courses. The Concepts in Biology course was specifically designed to better prepare teachers to teach life science in today's elementary and middle school environments based on the national science standards and the state science teaching model (see Fig. 1). Two science educators with backgrounds in biology and biology teaching worked to develop a course which addressed the content needed to teach elementary science as well as middle school life science and to demonstrate appropriate teaching materials and methods.

First, we literally turned the course around from the traditional presentation of material -- chemistry of the cell to the (usually rushed or omitted) ending point of ecology/ environmental science. Discussions with previous students led us to believe that they felt more comfortable and familiar with the concepts presented in the "bigger picture" areas of biology -- ecology and environmental science. This also made intuitive sense in terms of teaching because we would be starting with material that was part of the everyday lives of students, even if they had not fully made the necessary connections. It was our job to help them develop those connections and to understand the underlying concepts in these, and other areas of biology, using an activities-based focus on broad themes (cycles, patterns and change, systems and interactions, etc.) incorporating science process skills. We then proceeded to weave in needed content such as: ecological concepts, diversity of living organisms, genetics, taxonomic classification and the characteristics of plant and animal life, animal body systems, cell biology, and finally coming full circle to study some environmental issues relating in a very interdisciplinary fashion to all of the life sciences. This ending point also provides a logical lead into the final capstone course.

One goal of this course was to foster more positive student attitudes toward life science and to capitalize on both positive and negative experiences in helping students to see how teachers can influence students' interest in science. Initial data was collected using a questionnaire and survey regarding students' attitudes toward science based on positive and negative science experiences. Learning about students' attitudes toward science and prior experiences with science were important starting points in developing positive, "let's find out" approaches to teaching life science. One trend revealed in the data was that several of the students had had some degree of success in the traditional lecture and occasional demonstration format. Throughout the course, these students voiced a degree of discomfort and dissatisfaction with the opened-ended, hands-on format of the course. Students who had less success in traditional courses and initially had less positive attitudes toward science overall expressed near relief that biology could taught in a more interesting fashion. Based on the findings of this study, the biology course herein described continues to evolve and change to better accommodate students' understanding of biological concepts and more effective approaches to teaching science courses.

Concepts in Geology was developed to meet the Ohio Competency-Based Science Model, and the National Research Council's content standards for Earth Science. Course topics begin with minerals, then progress to Igneous, Metamorphic, and Sedimentary rocks. The history of the Earth, geologic time, fossils, the interior of the Earth, and plate tectonics follow. The Interior of the Earth is studied using earthquakes and seismic reflection and refraction principles (introduced first in Physics). The theory of plate tectonics, the Earth-Moon system and Meteorology round out this course offering. This course is content based (the only Earth Science the future teachers will receive in their training) and so the topics may be thought of as traditional. But the treatment of the topics is not. Each broad topic noted above is accompanied by hands-on activities designed to enrich the student's understanding of the topic under consideration. Real-time data available on the Internet/world-wide web is used to bring the nature of scientific inquiry alive for the future teachers.

Students come to geology having heard of the theory of plate tectonics, but are unclear as to the details of the paradigm. Virtually none understand how, for instance, scientists determine the boundaries or the nature of tectonic plates. The following is an example of how this course uses internet/world-wide web technology to bring scientific inquiry to the course in the context of plate tectonics. Students attending the university receive e-mail accounts and through their personal passwords, are able to access the internet/world-wide web. During the first week of the quarter students are given two world wide web site addresses. One is for the National Earthquake Information Center (http://www.neic.cr.usgs.gov), and Volcano World (http://volcano.und.nodak.edu). They are also provided with a physiographic chart of the oceans complete with longitude and latitude. They then plot the occurrence of earthquakes and volcanic activity over the course of a ten week quarter, using different symbols to plot deep and shallow quakes. When the topic of plate tectonics is encountered late in the quarter the students have substantially delineated the boundaries of some tectonic plates. They begin to understand the reasoning that scientists use to determine plate boundaries. Since deeper earthquakes are common at converging plate boundaries and shallow earthquakes dominate diverging boundary settings such as the Mid-Ocean Ridge, they internalize the concept of a thinner oceanic crust. The differences between volcanism at converging boundaries and intraplate volcanism (Hawaii) become topics for class discussion rather than professor's lecture. Geography and map skills are also enhanced.

The Capstone Course

Projects in Science, as the capstone course, is designed to be a culminating experience in which the students apply the science content and processes acquired through the previous classes in the design, implementation, evaluation, and communication of an investigation of their choosing. The projects are interdisciplinary in that the concepts and processes involved cut across discipline lines. For instance, students could choose to investigate the effects of pollution (air, water, or sound), including technological and societal impacts. The students would perform direct experimentation and data collection, utilize library and computer information resources, analyze and present their results. This course permits students to gain natural multidisciplinary, technological, and societal perspectives of how a science investigation is genuinely conducted. The students also are expected to explore the potential applications of how similar science experiences could be used in their future classrooms. The goals of the course are:

1) to further develop student understanding of the scientific process;

2) to develop students abilities to design, implement, evaluate, and communicate scientific investigations;

3) to develop student understanding of the relationships between science, technology, and society;

4) to further develop student understanding of the concepts learned in previous science courses in the program within an interdisciplinary, thematic, investigative environment;

5) to further develop and apply problem-solving, critical analysis, and decision-making skills and abilities within an interdisciplinary, thematic, investigative environment.

Further Science Education Preparation

When students have completed this sequence of specially designed science courses (see Fig. 2), they begin their professional sequence of education courses and experiences. The

Elementary School Science: Methods, Curriculum, and Materials course is designed to provide the developing elementary teacher with the central concepts, tools of inquiry, and structures of elementary school science enabling them to create learning experiences that make science meaningful for their future students. In this course, the preservice teachers acquire an understanding of how to utilize a variety of instructional strategies to encourage their students' development of conceptual knowledge, critical thinking, problem solving, and performance skills. Moreover, they learn how to plan for instruction based on knowledge of the national and state science standards, the nature of science, the nature of how students learn and develop, and how to accommodate differing approaches to learning such that the developing teacher can create instructional opportunities that are equitable and adaptable to diverse learners. The overarching goal of the course is to provide the prospective elementary teacher with a broad set of viable approaches to effectively teaching science. These approaches are couched within the framework of the nature of science and the nature of the learner. More specifically, this course is designed to actualize the following objectives:

1) the ability to plan and implement a constructivist, inquiry-based science program which challenges student to accept and share responsibility for their own learning;

2) the ability to select developmentally appropriate science content, adapt and design curricular materials that recognize and respond to student diversity and encourages all students to participate in science inquiry and learning;

3) the ability to design, manage, and manipulate the learning environment to create a situation for the student which is supportive of science exploration and inquiry;

4) the ability to understand how to access resources and guide students as they use science equipment and everyday materials, media and technological tools in such a way as they facilitate the acquisition of both declarative and procedural knowledge within the context of a safe and productive classroom environment;

5) the ability to engage and motivate students to pursue science inquiry and to facilitate the development of a community of learners that reflect attitudes and social values that are conducive to science inquiry;

6) the ability to design and implement instructional frameworks that provide opportunities for active explorations into the connections and interactions between science, technology, and other human endeavors such as mathematics, history, the arts, and humanities, and to explore those connections and interactions as they relate to personal and/or global issues.

The teacher preparation program at WSU incorporates a wide variety of field-based experiences prior to student teaching. Another teacher preparation option for individuals with undergraduate degrees who wish to enter the teaching profession is the Professional Year Program (PYP) which is part of the Goodlad network. The PYP is designed for individuals possessing an undergraduate degree to enter an intensive year-long program of clinical experiences and closely related course work, and after completion of the program to have teaching certification as well as a master's degree. An interdisciplinary science teaching master's degree is in development to individually tailor the science teaching and content needs of inservice teachers. Another aspect of the program that is in the development stage is to systematically pair preservice with "best practices" inservice K-12 teachers. This pairing aspect of the teacher preparation program will enable us to better sustain teacher professional development on both levels by more fully involving exemplary science teachers in preparing the next wave of classroom teachers.

Concluding Remarks

Being on a 10 week quarter system has serious draw backs, particularly when addressing the science content needs of elementary preservice teachers. This aside, the science educators are presently more concerned with and continue to work on the middle level component of the program as that area of certification is designed within the CEHS.

Regardless of the cognitive understanding students have of the science education standards and the need for process skills approach to science teaching to reach all students, departure from the lecture- memorization- regurgitation- teacher-centered- passive student model of science courses were not initially well-received by a number of students who have succeeded in that traditional mode. Recent data indicate that students are now, two years into the new program, more receptive and are actually welcoming the changes in the science courses. Perhaps we are doing a better job of explaining the importance to this type of science teaching, or perhaps the students early field experiences permit them to have a better conceptual understanding of children's science learning, or it may be a combination of these and other factors. The program as we have described it is, as it should be, an evolving program, dynamic in nature. We are learning along the way and more than willing to revisit original ideas and to change, design and redesign to best serve the preservice teachers and the inservice teachers involved in our program. Also, as a large proportion of local teachers are retiring within the next five years we feel that with this cohesive science education K-8 teacher preparation program in place our graduates can make a significant impact on effective science teaching in the Miami Valley area.

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Exploring the Use of Visual Learning Logs in an Elementary Science Methods Class

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Visual Learning Logs

Visual data such as photographs, drawings, and schematics play a vital role in the scientific enterprise. In the everyday world icons, symbols, and signs are pervasive and powerful forms of visual communication. As children learn to read and write they do so with the aid of pictures and photographs. In science teaching, learners interact with nontextual pictorial elements of instructional materials and are also often asked to sketch or draw their work.

The literature research on visual literacy is related to curriculum and instruction (Braden, 1987), to visual-verbal symbiosis (Braden, *1993),* to teaching visual literacy at the elementary, high school and college levels (Case-Grant, 1973; Beauchamp, 1991); to foreign language instruction (Morain, 1976); to international communication of ideas without words (Sondak & Sondak, 1991); and to interpretation of environmental signs (Horsley, 1988). Little was found on the role of visual literacy as a component of science literacy or of science teacher preparation.

The importance of creating visual representations is supported by Paivio's (1990) dual coding theory. Specifically, Paivio (1990) proposes that there are separate visual and verbal stores in memory. From this perspective, learning could be considered to be more effective when both verbal and visual memory traces have been created. The use of visual learning logs as we have done in this preliminary study also incorporates the advantages of techniques like concept mapping, in conjunction with reflective journal entries.

In this study we present work in progress that investigates the use of visual learning logs by preservice elementary teachers as one component of developing visual literacy for science teaching and learning. Visual learning logs (VLL) consist of free-form drawings (i.e., pictograms) produced by the preservice elementary teachers in the study in conjunction with weekly written journal assignments. The intent of VLL was not to illustrate the written journals, but rather to serve as an alternative to textual descriptions, explanations, interpretations and reflections on the course learning experiences.

Purpose

The purpose of the study is to explore the use of visual learning logs (VLL) as an alternative mode for thinking and communicating about experiences in an elementary science methods course that emphasizes developmentally appropriate, constructivist teaching. The ultimate aim of VLL is to improve science instruction for young children, including prereaders, early readers and normative English speakers. Specific questions investigated are

1. What kinds of information can be conveyed using VLL?
2. What kinds of ideas can be expressed better in VLL than in written journals?

Methodology

Subjects were 20 preservice teachers enrolled in an elementary science methods class at a university in Hawaii. Two were males. The class was culturally diverse, representing the four major ethnic groups in Hawaii: Caucasians, Japanese and Filipino Americans, and Hawaiian and Pacific Islanders, plus other ethnic groups. For this preliminary study, results are aggregated.

Procedure

The preservice elementary science teachers were instructed to submit a visual learning log in conjunction with a written journal entry each week throughout a semester. Their specific instructions were to "draw a pictogram (a visual learning log) showing what you learned and what it means to you. Include feedback on your feelings about your learning experience." They were told to regard their VLL as an alternative form of a journal. That is, their visual logs should convey their ideas visually and not be dependent on information in their written journals.

The preservice teachers were free to develop their own nontextual representational forms to depict and interpret their learning experiences. For affective representations, the class discussed the possible use of visual affective symbols such as a smiling face or other facial expressions, or stylized affective ratings such as thumbs-up or thumbs-down symbols. To connect the learning activities with time and place in memory, students were encouraged to visually link their classroom experience with something noteworthy about each day.

Preliminary work reported in this session examines VLL collected over a sampled two-week period, plus end-of-semester written comments from the students on the usefulness of VLL. To determine the kinds of information preservice teachers considered important in their visual representations of the science methods class, a categorization system was devised by the authors to carry out content analyses of the VLL. The categories are listed under Data Analysis and Findings.

Students were asked at the end of the semester to look back over both drawn VLL and written textual journals and respond to "What kinds of ideas can you better express using a pictogram, not a written journal?" Responses were analyzed using a modification of the coding system used for VLL content analysis, then summarized.

Data Analysis and Findings

Data analyses consisted of calculating frequencies for each of the content analysis categories which were treated as mutually exclusive. Results indicated that the majority of VLL images consisted of depictions of science activities carried out in class (22%), group learning activities (22%), affect (13%), and science education concepts (11%). Images in other categories with lower percentages included descriptions of events in the daily environment (10%), nature of science (8%), activities chosen by groups (5%), general education concepts (5%), and science teaching resources (3%). Uncodeable responses were less than 1%.

These coded VLL findings indicate that preservice teachers are experiencing and remembering science teaching in their methods class as active learning. Additionally, science is experienced as a social learning process and science content and process are connected to real world situations. These findings are consistent with course objectives.

Examination of written comments at the end of the semester revealed that students felt that compared to written journals, VLL better express

1. An immediate way for the teacher to see at a glance what the learner has experienced and selected as important. Commented a student, "When I look at the picture it reminds me and I can clearly picture the activity done in class that day."

2. Affective and aesthetic dimensions of science teaching and learning. They particularly noted that young prereaders could provide affective feedback with such images as smiling or frowning faces. One preservice elementary teacher said, "Using a pictogram, you can express aesthetic, emotional responses to activities and lessons that cannot otherwise be expressed in writing. Another said, "You can also tell what lessons were great for students because of the ratings that are used on the drawings. "

3. The steps or processes involved in a hands-on activity. Visual depiction makes the process appear more realistic than using words alone. As stated by a student, "I could express my ideas using a pictogram better by drawing out the activities done."

4. Observations and details that are "hard to describe in words" including the use of realistic colors. As one student said, "You can show colors and results rather than just writing about them." Said another, "Pictograms show more detail on what something looks like."

5. An alternative means of expression for visual, nonverbal learners. As one of the male students said, "I just think overall it helps students who have trouble expressing themselves with writing. I personally enjoyed the pictograms compared to our written journals." Others mentioned "Greater opportunity for individual expression" and "Greater variety." Another said, "This also helps children who have a different learning style through color/pictures rather than just words."

6. Alternative methods for teaching and learning, including
    - engaging nonreaders, prereaders and ESL students in science learning.
    - reviewing lessons and sequences of lessons
    - evaluating and monitoring student progress, and
    - teacher's self-evaluation of lesson effectiveness.

Working Conclusions

Within the context of the science methods class, elementary preservice teachers are often "science shy." They have limited prior experience in science courses, and most often these courses focus on traditional teacher-centered pedagogy including lectures, note-taking, and multiple-choice tests. Findings from this study suggest that VLL provide an alternative way to help preservice elementary teachers gain confidence in their science teaching ability and to prepare them in use of unfamiliar constructivist pedagogies. Because VLL are not dependent on text, including the use of scientific or educational terminology, from the outset of the course methods students have a way of recording, reflecting, and conversing on what they learned, how it was learned, and how it was taught. VLL supported written learning logs and use of concept maps in the methods class. Findings thus far suggest that VLL

I. Create alternative ways for preservice elementary science teachers to meaningfully depict their science methods class experiences and to portray their own emerging understandings of science teaching and learning.

2. Support constructivist approaches to science teaching and draw upon multiple modalities for learning.

3. Provide a means of combining minimal verbal oral and written expression with concrete visual representations of complex ideas. Suggested here is that learners can engage with complex ideas before and during the process of mastering associated verbal learning.

4. Allow an outlet for succinct affective feedback. This is an area where young children often lack effective verbal skills. This suggests that visual learning logs may be a useful tool for young children as well as their teachers.

5. Can be used to promote reflection, for summary or review, and for evaluation.

These preliminary findings point to the need for further research on the effectiveness of VLL as heuristic devices both in elementary science methods classes and with prereaders, nonreaders and ESL students. Research is needed comparing the effectiveness of VLL and written learning logs in preservice elementary science methods classes. Research is also needed on the links between visual literacy and scientific literacy and on the learning effectiveness of dual coding using visual and verbal memory. Additional research is needed on preparing teachers for visual dimensions of science teaching and learning.

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CONSTRUCTIVIST TEACHING PRACTICES: PERCEPTIONS OF TEACHERS AND STUDENTS

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Constructivist Practices

Years of research on change in schools have provided elements of practice that work and do not work. The process of change involves three phases (1) initiation: deciding on an agenda and beginning work; (2) implementation: putting the change process into action; and (3) institutionalization: change becoming embedded into the curriculum with continuous learning and improvement taking place (Stiegelbauer, 1994).

Systemic reform aims to change teaching and learning practices (Cohen, 1995). Constructivist teaching practices in science and mathematics classrooms are intended to produce much more challenging instruction for students and thus, produce improved student learning. Structural changes have a high symbolic value. It communicates that schools are serious about change. However, research has shown that changes in structures are not directly related to changes in teaching and learning (Elmore, 1995). The key questions then are; (1) how to change instruction so that teachers teach differently and students learn more, (2) what elements of practice have to be in place for structure to work and (3) what evidence shows that changes in structure are actually related to changes in instruction and learning practices.

Research shows that the relationship between structural change in schools and changes in teaching and learning are related to elements such as; knowledge and skills of teachers, professional values and commitments and empowerment (Cohen, 1995; Elmore, 1995). Many times teachers approach systemic reform with little background knowledge of the type of instruction that is necessary for change to occur. Most teachers learn to teach in a traditional manner. Reformers need to focus first on developing teachers' knowledge and skills before they focus on changing structure. Teachers need the opportunity for staff development so they might learn to teach differently. In addition, teachers need the opportunity to develop shared goals, expectations and beliefs about what good teaching is, how to carry out instruction and then create an organizational structure that coincides with those goals, expectations and beliefs (Elmore, 1995). A change has to be clear in its goals and procedures and have a role within an organization that will lend to long-term support (Stiegelbauer, 1994).

Successful systemic reform depends on more than improved teacher knowledge and skills. It requires changes in values and beliefs of acceptable professional practices and students' achievement ability. Change has to be valued by the organization and by the members within the organization (Steigelbauer, 1994). The organization should develop a shared vision of what its change should look like. In addition, teachers must believe that students are capable of advanced work in science and mathematics. They must be committed to working with students in pursuit of improved learning. The early involvement of everyone in problem identification and the need for change helps develop commitment. This commitment increases as teachers master instructional practices and students' increase their capacity to learn.

Research has also shown that empowerment has a significant impact on instructional practices and measured student achievement (Elmore, 1995). Empowerment means giving people within an organization responsibility and support to actualize that responsibility. When teachers share in decision making, they have a vested interest in structural change. Change has to have practical outcomes for both teachers and their students.

These elements of practice: teachers' knowledge and skills of instructional practices and learning, professional values and commitments and empowerment are crucial to the progress of systemic reform.

This study focused on the elements important to systemic reform. This study also examined constructivist classroom instructional practices as viewed by teachers and students. It was part of an evaluation effort after the second year of a systemic reform change process in a large urban school district. A constructivist vision statement was developed for science and mathematics teaching, learning and staff development.

> Constructivism leads to new beliefs about excellence in teaching and learning and about the roles of both teachers and students in the process. In constructivist classrooms, students are active rather then passive; teachers are facilitators of learning rather than transmitters of knowledge (Stein et al., 1994, p. 26).

Extensive staff development seminars for science and mathematics teachers focused on the constructivist vision. The evaluation effort included teacher, student surveys, parent and unit head focus groups, observations of staff development sessions and case studies of selected schools. Teacher and student surveys served to probe perceptions of the frequency of use of various constructivist teaching and learning practices in keeping with the systemic reform goals. Findings from this study indicated both teachers and students were active participants in a changing school curriculum and (a) the curriculum covered the elements of constructivist teaching and learning, (b) the teachers implemented this curriculum on a regular basis, and (c) the students reported regular experiences with constructivist teaching and learning practices.

Traditional Instruction

In the 1970's and 1980's research was a dominant source for ideas about how to teach. This resulted in direct instruction, where teachers directly instructed students on the content or skills to be learned and provided practice until the learning was internalized (Steffe & Gale, 1995; Riber, 1992). Direct instruction is effective when the goal of instruction is to have students reproduce factual knowledge. However, when we make a distinction between training (to direct learning by transmitting knowledge) and teaching (to facilitate learning through hands-on experiences) we see how direct instruction can be of limited value.

Constructivist Teaching

Research shows that constructivist teaching has only been widely accepted in mathematics and science since the early 1980's (Steffe & Gale, 1995). Cognitive psychology has provided a basis for constructivist teaching. Piaget (1971) was one of the early contributors to this research. He suggested that new experiences are received through existing knowledge, a process of assimilation and accommodation. Learners construct knowledge as they attempt to bring meaning to their experiences. Glaserfield (1995) was another contributor of constructivist research. He explains that constructivism is a theory of rational knowing. Learners construct knowledge themselves on the basis of subjective experiences.

Constructivist teaching emphasizes thinking, understanding, reasoning and applying knowledge while it does not neglect basic skills. It is based on the idea that learners construct their own knowledge, rather than reproduce someone else's knowledge. In their book, The Young Child as Scientist: A Constructivist Approach to Early Childhood Science Education, Chaille and Britain (1991) point out in a constructivist classroom the teacher is no longer the transmitter of knowledge but the facilitator of learning. The teacher as controller of students is a myth (Tobin & Dawson, 1992). The facilitator of learning needs to keep in mind that instruction will vary depending on the learners prior knowledge, current interest, and level of involvement (Chaille & Britain, 1991). A skillful teacher will understand that students have existing knowledge; which may be incomplete or wrong, but will guide perceptions and initiate understandings (Tobin & Dawson, 1992).

Constructivist Teaching Practices

Constructivist teaching is guided by five basic elements; (1) activating prior knowledge, (2) acquiring knowledge, (3) understanding knowledge, (4) using knowledge, and (5) reflecting on knowledge (Tolman & Hardy, 1995). Activating prior knowledge is very important since what is learned is always learned in relation to what one already knows. When teachers are familiar with a students' prior knowledge they can provide learning experiences to build on these existing understandings (Steffe & D'Ambrosio, 1995). Prior knowledge can be activated in many ways for example, by asking students what they know, by brainstorming, by doing semantic mapping, by predicting outcomes or by performing some skill or process. As Simon (1995) points out in his article, "Elaborating Models of Mathematics Teaching", teacher's knowledge is constantly being constructed as he or she interacts with students. Gurney (1995) states that articulation of prior knowledge acquaints teachers with students' thinking, affording insights from which to plan instruction.

Research has shown that students must acquire their own knowledge in a way that helps them determine the extent to which it fits their existing knowledge. Shchlenker, Yoshida and Pery (1995), describe a lesson, ("Muscle Building"), where students' build their own model of a muscle. In each step, students have to interpret new knowledge in the context of what they already know.

Once students have been exposed to new knowledge, the process of understanding knowledge begins. Teachers can assist in this development by providing many experiences that motivate students to explore this new knowledge and have them communicate their interpretations of it. Research indicates that communicating knowledge is essential for understanding (Fensham & Gunstone, 1994). There are many ways in which knowledge can be shared for example, conferencing between teacher and student, small group activities in which students voice their interpretations, oral reports, projects, role playing and demonstrations.

Students must activate prior knowledge in order to extend and refine this knowledge. The most effective activities for knowledge use are problem-solving activities (Steffe & Gale, 1995). This encourages students to continue to examine and build on their knowledge. When students work in groups to solve problems, it is more useful than when they work alone because they have the opportunity to constantly voice ideas and receive feedback (Chaille & Britain, 1991).

Reflection refers to understanding what one knows. This requires providing activities that ask students to look back at what they have learned (Tobin & Dawson, 1992). Journal writing is an especially good technique to promote reflecting.

Purpose of the Study

The purpose of this study was to examine and compare the frequency of use of selected constructivist classroom instructional practices as perceived by teachers and students and to provide information about the process of systemic reform. Surveys were designed to assess the extent to which an Urban Systemic Initiative has been implemented within the schools. Significance for this study rests in four arguments: (a) establishment of baseline data on implementation of the elements of constructivist teaching practices (1996), (b) establishment of baseline data on students reporting experiences with constructivist practices (1996), (c) measuring changes in baseline data (a & b above) that will impact a large population (1997), and (d) extensive research. This study serves as a baseline for determining systemic reform change and future needs. Second, baseline data from this study will provide evidence of the implementation of regular constructivist teaching practices and learning experiences. Third, the findings of this research are likely to have implications for a large population and will be useful to science and mathematics educators. Finally, this study will attempt to examine constructivist instructional strategies used currently in science and mathematics classrooms.

For this investigation, the researcher defined constructivist instructional strategies that support constructivist learning as active learning with hands-on experiences that emphasize process and constructing meaning from these experiences and from prior knowledge. Constructivist teachers facilitate learning by assisting students in constructing knowledge. Specific research questions examined included:

1. How frequently do teachers report using constructivist practices in in their classrooms?
2. How frequently do students report experiencing constructivist practices in their classrooms?
3. How do the reports of teachers and students compare with regard to using constructivist teaching practices?
4. Is there a difference in the school level (elementary, middle, high school) of the teachers with regard to the reports of using constructivist practices?
5. Is there a difference in science and mathematics teachers with regard to the reports of using constructivist practices?
6. Are there any differences in the responses of science and mathematics teachers reporting constructivist practices at various school levels (elementary/science, middle school/science, high school/science, elementary/mathematics, middle school/mathematics, high school/mathematics)?

Method

Sample

The sampling units were existing fourth, eighth and tenth grade classrooms in a large urban school district. Fifty-four schools were randomly selected from a stratified sample, stratified by school level (elementary, middle and high school) and by tier (representing the degree of implementation of the systemic reform effort tier 1, 2 and 3).

A two stage sampling process was used for teachers. The first stage was the random selection of schools by tier (ten elementary, five middle and three high schools). The second stage consisted of asking all mathematics and science teachers within each school to complete the teacher survey (n = 570).

In addition, a three stage sampling process was used for students. The first stage consisted of randomly selecting schools by tiers (ten elementary, five middle and three high schools). For the second stage, two homeroom classrooms from the fourth, eighth and tenth grades were randomly selected from these schools. The third stage consisted of asking all of the students in each of these homerooms to complete the survey instrument (n = 1080).

Response Rate

Completed surveys were received from forty-nine of the fifty-four schools for a 91% school response rate. Completed surveys were received from two hundred eighty-nine teachers for a 51% response rate and eight hundred sixty-two students for a response rate of 80%.

Design

A teacher survey (33 items) and a student survey (39 items) were developed to determine the frequency of various instructional practices. The teachers marked their questionnaires by indicating how often they practiced these constructivist instructional practices by circling a response for each item (1 = almost never, 2, 3 = weekly, 4, and 5 = almost daily). The students marked their questionnaires by circling a response to indicated how often they experienced constructivist practices for each item (1 = never, 2 = sometimes and 3 = almost everyday). Teacher responses were collapsed into categories (#1 and #2 responses = 1 (never), #3 responses = 3 (weekly), #4 and #5 responses = 5 (almost daily)). Parallel specific contructivist teaching survey items were selected from both teacher and student surveys and included the following areas:

1. The discussion of careers in mathematics and science technology.
2. The use of manipulative materials and hands-on activities to discover principals and relationships in mathematics and science classrooms.
3. The frequency of use of computers in mathematics and science instruction.
4. The frequency of use of calculators in mathematics and science instruction.
5. The frequency of discussing African-American and other minority groups (multicultural perspectives) in mathematics and science.
6. The frequency of use of group activities in which students work cooperatively

in solving problems.

7. The frequency of use of projects in mathematics and science classrooms.
8. The frequency of writing in mathematics or science journals.
9. The frequency of opportunities for students to make choices about what they study in mathematics and science classrooms.
10. The frequency of maintaining portfolios of mathematics or science work to reflect growth over time and to document evidence of learning.
11. The frequency of personal conferences to reflect on progress and accomplishments in mathematics and science classrooms.
12. The frequency of using models to represent concepts in mathematics and science.
13. The frequency of opportunities to exercise mathematics or science skills.

As a part of a previous study, teachers were asked to indicate their perceptions of the adequacy of curriculum in the areas of mathematics and science (teachers survey section B) in 1993 and again in 1996. Teachers indicated how adequate they felt the curriculum was by circling a response for each item (1 = not at all adequate, 2 = somewhat adequate, 3 = adequate enough). The following items appeared on both surveys:

1. The development of problem solving skills.
2. The development of relationships between mathematics, science, and other disciplines.
3. The adequacy of how the curriculum relates to the needs of urban students.
4. The preparation of students for a college education.
5. The preparation of students for local and national science tests.
6. The preparation of students for future jobs.
7. The development of practical skills to use scientific instruments, calculators and computers.

8. The adequacy of how the curriculum relates to social issues relevant to the student.

Teachers' opinions about the adequacy of the curriculum has changes over this three year period during the implementation of this systemic reform process. Overall, teachers reported significant improvements in the science and mathematics curriculum between the 1993 and 1996 surveys. Significant improvements were noted in the adequacy of the curriculum in all areas, ($p < .05$) except for mathematics teachers in the area of preparation of students for local and national test and relating the curriculum to issues relevant to students. Table I provides a comparison of teacher views from 1993 to 1996.

Table I
Changes in Teachers Views of Adequacy of Curriculum From 1993 to 1996

Survey Item #	Elements of Curriculum	Math 1993	Math 1996	Sign Diff.	Science 1993	Science 1996	Sign Diff.
B-6	problem solving	1.9748	2.3459	p < .01	1.8944	2.3906	p < .01
B-7	relationship between math and science	1.748	2.1375	p < .01	1.7888	2.2835	p < .01
B-8	urban student needs	1.76	1.956	p < .05	1.7778	2.0233	p < .01
B-9	college	1.912	2.2201	p < .01	1.9	2.1742	p < .01
B-10	test	1.9274	2.0705	n.s.	1.9074	2.145	p < .01
B-11	future jobs	1.84	2.0449	p < .01	1.775	1.9845	p < .01
B-12	scientific instruments	1.935	2.1188	p < .05	1.8037	2.0458	p < .01
B-14	societal issues	1.7236	1.8065	n.s.	1.7702	1.9766	p < .01

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Instrument

The researcher used a teacher and student survey developed to determine the frequency of high quality curriculum covering elements of constructivist teaching practices. These instruments were found to be reliable using internal consistency techniques. The teachers instrument had an internal consistency reliability coefficient of .91 and the students instrument had an internal consistency reliability coefficient of .78.

Data Collection and Analysis

Using the teacher and student survey, average responses of constructivist items on the teacher survey were calculated and compared with similar items on the student survey. Next, similar comparisons were made by school level (elementary, middle and high school) and by subject area (mathematics and science).

Results

Data taken from the surveys were analyzed for each research question.

Question 1: How frequently do teachers report using constructivist practices in their teaching?

In answering this question, data obtained from the teachers survey titled "Curriculum and Practice" (section IA) served as the primary source of information. From the data it was learned that the frequency of using constructivist practices at least weekly was 50% or greater in all areas with one exception, using computers in mathematics and science instruction (28%). It should be noted that technology resources are being phased in across the school district and at the time this data were collected, these resources were not currently available to all students.

The majority of teachers (93%) report that they regularly (weekly or more often) use group activities in which students work cooperatively to solve problems. This data indicates that most teachers tend to provide a range of activities to promote active learning. Table II gives a breakdown of the percentages of instructional constructivist practices used by teachers weekly of more often.

Table II
Percents of Teachers Indicating use of Constructivist Practices Weekly or More Often

Question #	Teacher Survey Item #	Elements of Constructivist Implementation	Number of Teachers Responding	Percentages	Mean	Mode
1	I.A. 1	careers	275	71.00%	3.2	3
2	I.A. 6	manipulative	279	90.00%	3.7	3
3	I.A. 8	computers	270	28.00%	2.1	1
4	I.A. 9	calculators	276	66.00%	3.1	3
5	I.A. 13	multicultural	279	59.00%	2.9	2
6	I.A. 14	group activities	278	93.00%	3.9	4
7	I.A. 19	projects	275	56%	2.9	2
8	I.A. 20	write about	272	78.00%	3.4	3
9	I.A. 22	choices	274	57.00%	2.7	2
10	I.A. 24	portfolios	274	54.00%	2.8	3
11	I.A. 25	conferences	275	54.00%	2.8	2
12	I.A. 27	models	276	90.00%	3.8	4
13	I.A. 29	exercises	279	96.00%	4.1	5

Question 2: How frequently do students report experiencing constructivist practices in their classrooms?

Classroom student surveys, asking how frequently they experience constructivist practices, "In Their Mathematics Classroom" (student survey sections I) and "In Their Science Classroom" (student survey section II) provided data for this question. Student survey responses were separated by subject (student survey section I mathematics and section II science). These data provided information on the amount of constructivist instructional practices that students experienced in their classrooms. These data revealed the majority of the students do experience constructivist practices in their classrooms. The percent of students experiencing these constructivist practices at least weekly was greater than 50% for twenty of the twenty-six items. The only exceptions found were using computers in science class, (29%) using computers in mathematics, (42%) using calculators in science class, (39%) integrating multicultural aspects into science instruction, (48%) and integrating multicultural aspects into mathematics instruction (44%). Table III provides a distribution of constructivist learning experiences. Based on these findings it is clear that students are not passively absorbing information, but are actively involved in constructing meaning from many experiences.

Table III
Percents of Students Wxperiencing Constructivist Practices Weekly or More Often

Question #	Student Survey Item #	Elements of Constructivist Implementation	Number of Student Responses	Percentage	Class	Mean	Mode
1	I. 8	careers	731	57.00%	math	1.7	2
1	II 8	careers	720	58.00%	science	1.7	2
2	I. 19	manipulative	741	87.00%	math	2.2	2
2	II. 19	manipulative	700	82.00%	science	2.1	2
3	I. 9	computers	729	42.00%	math	1.5	1
3	II. 9	computers	709	28.00%	science	1.3	1
4	I.10	calculators	731	90%	math	2.3	2
4	II. 10	calculators	713	40.00%	science	1.5	1
5	I. 16	multicultural	726	44.00%	math	1.5	1
5	II. 16	multicultural	708	48.00%	science	1.6	2
6	I. 4	group activities	734	85.00%	math	2.1	2
6	II. 4	group activities	722	93.00%	science	2.3	2
7	I. 5	projects	729	55.00%	math	1.6	1
7	II. 5	projects	708	71.00%	science	1.9	2
8	I. 12	write about	723	50.00%	math	1.7	1
8	II. 12	write about	711	55.00%	science	1.8	1
9	I. 11	make choices	718	61.00%	math	1.9	1
9	II. 11	make choices	709	52.00%	science	1.7	1
10	I. 13	portfolios	730	66%	math	1.9	2
10	II. 13	portfolios	703	70.00%	science	2	3
11	I. 17	conferences	726	79.00%	math	2	2
11	II. 17	conferences	708	79%	science	2	2
12	I. 18	models	732	64.00%	math	1.7	2
12	II. 18	models	702	78.00%	science	2	2
13	I. 2	math homework	722	97.00%	math	2.7	3
13	I. 3	prob. from text	740	94.00%	math	2.5	3
13	I. 6	worksheet	732	95.00%	math	2.3	2

Question 3: How do the reports of teachers and students compare with regard to using constructivist teaching practices?

The researcher compared certain teacher responses, "Curriculum and Practice" (teacher survey IA items) and student responses, "In Your Mathematics Class"(student survey I items) and "In Your Science Class" (student survey II items) to determine the relationship between their perceptions of the frequency of constructivist practices in their classrooms. The researcher could not do analysis to correlate these responses since teachers could not be linked with their respective students. Instead the researcher compared average responses of teachers and students for each of the specified questions (see Table IV).

Based on these data there are strong relationships between teacher and student reported perceptions of the frequency of using constructivist practices in their classrooms in the areas of group activities, (teachers = 93%, mathematics students = 85%, science students = 93%) and making choices, (teachers = 57%, mathematics students = 61%, science students = 52%).

Minimal differences were noted in all other areas with the exceptions of computer use, (teachers = 28%, mathematics students = 42%) calculator use, (teachers = 63%, mathematics students = 90%, science students = 40%) projects, (teachers = 56%, science students = 71%) writing in journals, (teachers = 79%, mathematics students = 50%, science students = 55%) portfolios, (teachers = 54%, science students = 70%) conferences, (teachers = 54% mathematics students = 79% science students = 79%) using models, (teachers = 90%, mathematics students = 64%, science students = 78%) and doing exercises (teachers = 97%, science students = 73%).

Table IV
A Comparison of Perceptions of the use of Constructivist Practices

Question #	Elements of Constructivist Implementation	Teacher Survey Item #	Student Survey Item #	Teacher %	Mathematics Student %	Science Student %
1	careers	I.A.1	I 8 & II 8	71.00%	57.00%	57.60%
2	manipulatives	I.A.6	I 19 & II 19	90.00%	87.00%	83.30%
3	computers	I.A.8	I 9 & II 9	28.00%	41.00%	27.80%
4	calculators	I.A.9	I 10 & II 10	66.00%	90.00%	39.30%
5	multicultural	I.A.13	I 16 & II 16	59.00%	44.00%	47.80%
6	group activities	I.A.14	I 4 & II 4	92.00%	85.00%	92.70%
7	projects	I.A.19	I 5 & II 5	56.00%	55.00%	71.20%
8	write about	I.A.20	I 12 & II 12	78.00%	50.00%	55.30%
9	choices	I.A.22	I 11 & II 11	56.00%	61.00%	52.30%
10	portfolios	I.A.24	I 13 & II 13	53.00%	66.00%	70.40%
11	conferences	I.A.25	I 17 & II 17	54.00%	79.00%	79.10%
12	models	I.A.27	I 18 & II 18	90.00%	64.00%	78.10%
13	exercises	I.A.29	12 & 13	97.00%	98.00%	73.30%

Question 4: Is there a difference in the school level (elementary, middle, high school) of the teachers with regard to their reports of using constructivist practices?

To address this question data were collected from teacher surveys and then separated by school level (elementary, middle school, high school). An examination of this data revealed the following distribution of the frequency of constructivist practices used by teachers at different school levels (see Table V). Elementary and middle school teachers report using constructivist practices in their classrooms most often (50% use it weekly or more often in all areas with the exception of computers 43%). The percentage of use of constructivist practices was highest for the elementary school level. Overall, high school teachers reported using constructivist practices least often, with only seven of the thirteen areas being greater than 50%.

There was a notable decrease in reported constructivist teaching practices from elementary to high school with regard to the use of computers, (elementary 43% and high school 23%) multicultural aspects, (elementary 91% and high school 49%) projects, (elementary 63% and high school 48%) and portfolios (elementary 61% and high school 46%).

Table V
Constructivist Practices as Reported by Teachers at Various School Levels

Question #	Teacher Survey Item #	Elements of Constructivist Implementation	Elementary School Teacher	Middle School Teacher	High School Teacher
1	I.A. 1	careers	73.00%	67.00%	72%
2	I. A. 6	manipulatives	94.00%	87.00%	88%
3	I. A. 8	computers	43.00%	20.00%	23.00%
4	I. A. 9	calculators	60.00%	62.00%	76.00%
5	I.A. 13	multicultural	91.00%	64.00%	49.00%
6	I. A. 14	group activities	93.00%	94.00%	92%
7	I. A. 19	projects	64.00%	58.00%	48.00%
8	I. A. 20	write about	76.00%	79.00%	80%
9	I. A. 22	choices	54.00%	71.00%	46.00%
10	I. A. 24	portfolios	61.00%	55.00%	46.00%
11	I.A. 25	conferences	58.00%	56%	49.00%
12	I. A. 27	models	90.00%	94.00%	85%
13	I. A. 29	exercises	97.00%	97.00%	95%

Question 5: Is there a difference in the responses of constructivist teaching practices in subject area (science or mathematics) of the teachers with regard to the reports of using constructivist practices?

Data for this question were examined by separating teacher certification (science, mathematics) and looking at their responses to survey items, "Curriculum and Practice" (teacher survey section IA). The tally on subject area and use of constructivist practices is shown in Table VI. In these classrooms the only differences found were with the use of calculators, (survey item IA-13), integrating multicultural perspectives (survey item IA-14), and the use of projects to observe students at work (survey item IA-19). Science

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teachers integrate multicultural perspectives into their curriculum and use projects more often than mathematics teachers. Mathematics teachers use calculators with their instruction more often than science teachers.

Question 6: Are there any differences in the responses of teachers reporting constructivist practices after combining grade level and subject area (elementary/science, middle school/science, high school/science, elementary/mathematics, middle school/mathematics, high school/science)?

The data shows some significant differences with regard to constructivist practices after combining grade and subject area (see Table VI). In the elementary level noticeable differences in frequency of use of constructivist instructional practices were found for the use of calculators (elementary/mathematics 66%, elementary/science 53%). At the middle school level the following differences were noted in the frequency of use of constructivist practices; the use of calculators, (middle school/mathematics 76%, middle school/science 51%) integrating multicultural aspects, (middle school/mathematics 54%, middle school/science 63%) use of projects, (middle school/mathematics 45%, middle school/science 54%) writing, (middle school\mathematics 73%, middle school\science 84%) and using portfolios (middle school/mathematics 56%, middle school/science 48%). Differences were also noted at the high school level with the use of projects (high school/mathematics 32%, high school/science 62%) writing, (high school/mathematics 76% high school/science 88%) and making choices (high school/mathematics 46% high school/science 56%).

Table VI
Constructivist Teaching Practices used at Least Weekly Separated by Level and Subject

Question #	Teacher Survey Item #	Elements of Constructivist Implementation	Elem./Math Teachers	Mid/Math Teachers	High/Math Teachers	Elem./Sci Teachers	Mid/Sci Teachers	High/Sci Teachers
1	I. A. 1	careers	69.00%	74.00%	74.00%	72.00%	75.00%	76%
2	I.A. 6	manipulatives	88.00%	85%	81%	91.00%	89.00%	96.00%
3	I. A. 8	computers	32.00%	26.00%	21.00%	35.00%	21.00%	20.00%
4	I. A. 9	calculaters	66.00%	76.00%	87.00%	53.00%	51.00%	58.00%
5	I. A. 13	multicultural	62.00%	54.00%	45.00%	70.00%	63.00%	55.00%
6	I.A. 14	group activities	88.00%	95.00%	87.00%	93.00%	95.00%	95.00%
7	I. A. 19	projects	53%	45.00%	32.00%	61.00%	54.00%	62.00%
8	I. A. 20	write about	71.00%	73.00%	76.00%	79.00%	84.00%	88.00%
9	I. A. 22	choices	64.00%	57%	46.00%	66.00%	61.00%	57.00%
10	I. A. 24	portfolios	55.00%	56.00%	47.00%	56.00%	48.00%	45.00%
11	I. A. 25	conferences	57.00%	56.00%	44.00%	56.00%	50.00%	51.00%
12	I. A. 27	models	93.00%	96.00%	86.00%	91.00%	96.00%	85.00%
13	I. A. 29	exercises	94%	98.00%	95.00%	95.00%	99.00%	98.00%

Discussion

Understanding the elements of practice which influence the success of systemic reform opens the door to improving teaching and learning practices. The findings of this study document the nature and extent of growth and future needs of a systemic reform process, resulting from extensive staff development seminars and intensive classroom constructive instructional practices. One form of systemic reform growth was evident in the teachers' opinions about how the adequacy of the curriculum has changed during the implementation of this process (see changes in teachers views from 1993 to 1996, Table I). It is our speculation that the reported improvements are associated with a number of components including; 1) adoption of a shared vision statement, 2) broad support involving the school and community in the systemic reform process 3) staff development workshops focusing on constructivist instructional techniques and where constructivist teaching strategies were modeled by workshop instructors, 4) administrative support (unit heads, principals, area office and central office supervisors) and 5) continuous monitoring of the change effort.

Another evidence of systemic reform process can be found in the use of constructivist practices by science and mathematics teachers. Teachers identified the frequency with which they implemented various elements of constructivist teaching practices (Table II). These data indicated that teachers implement constructivist practices regularly in their classrooms. The frequency of implementing constructivist practices weekly or more often was 50% or greater in most areas. The only exception was using computers (28%), although this was due to the fact that computers are just now being phased in across the school district. These constructivist elements consisted of providing hands-on experiences using manipulative materials, using computers in instruction, using calculators in instruction, integrating multicultural aspects into the curriculum, providing group activities for students to problem solve, using projects to assess student learning, offering opportunities for students to write and communicate their experiences, maintaining student portfolios, providing several one-on-one conferences to discuss student progress, using models to teach concepts and offering many opportunities for students to do exercises.

The responses of teachers about their use of constructivist practices were validated by student responses (see Table III for student responses). Students generally agreed with teachers about the frequency of use of constructivist instructional practices (see Table IV). The most frequent instructional experience reported by students was working in groups (mathematics students 85%, science students 93%). This supports the research on the value of group learning (Steffe & Gale, 1995). These findings suggest that minimal differences in perceptions of teacher and student responses are present.

The reported use of constructivist instructional practices was further examined by school level. Strong relationships in the perceptions of teachers and students were present in the areas of group activities and making choices. In general both teachers and students agreed that constructivist teaching was taking place on a regular basis (see "Constructivist Practices as Reported by Teachers at Various School Levels", Table V). The percentages of use of constructivist practices was highest for elementary school level. High school level reported using constructivist practices least often. This difference in school level might be attributed to the heavier emphasis on subject matter content over process as one progresses from elementary school to high school. Higher grade level teachers might feel the pressure to teach more traditionally to cover the more extensive amount of content at that level.

In addition, differences in the response of science and mathematics teachers were examined with regard to their reported use of constructivist instructional practices (see Table VI). These findings suggest that science teachers use constructivist practices more often than mathematics teachers. However, mathematics teachers use computers, calculators and conference with their students more often than science teachers.

The reported changes and use of contructivist instructional practices will be monitored in successive years of the systemic change process. The preliminary evidence provided here indicate that teachers are using constructivist instructional practices and have changed their views about the adequacy of the curriculum during this systemic change process.

Conclusion

The findings of this study provide evidence that; 1) teachers feel the science and mathematics curriculum is much more adequate since the implementation of the systemic reform process, 2) teachers report using a variety of constructivist strategies in their classrooms (weekly or more often) and 3) students also report experiencing constructivist practices in their classrooms. Overall, teachers and students report using several constructivist practices in their classrooms.

The necessary elements of systemic reform and constructivist practices appear to be present in this school district. Teachers and students report using activities that support activating prior knowledge. In addition, teachers appear to be aware of the most current research, that students must acquire their own knowledge as a part of the constructivist theory. The majority of teachers report using models (90% weekly of more often) and hands-on experiences (90% weekly or more often). Dialog between teacher and student through conferencing is essential for a student to understand knowledge. Teachers and students reported conferencing 54% weekly or more often, having group activities (93%) and using projects (56%). Students use their new knowledge through problem solving (93% weekly or more often) and reflect on knowledge through writing (78%).

A curriculum built upon constructivist beliefs is concerned with the aspects of learning in which students make sense of experiences in terms of existing knowledge. Research has shown that much can be gained by the infusion of constructivism into instructional design. It can provide environments in which learning is achieved through discovery and inquiry. It offers promise in the development of successful learning experiences by producing students who think, apply knowledge and solve problems.

Future Research

Inferences can be drawn from these findings, if teaching, learning and staff development are planned with a shared vision, then it is possible to make changes in classroom instruction to improve the learning environment. Research associated with improving student outcomes indicates that constructivist practices are educationally advantages for all students. However, additional research is needed to continue assisting science and mathematics teachers, and indeed all teachers, to demonstrate competency in constructivist teaching practices. A constructivist approach to in-service teachers may require us to elicit prior knowledge held by teachers about teaching and learning. Additional follow-up studies will help us determine what is necessary to provide teachers with the skills and motivation needed to enable them to continue experiencing growth in developing the knowledge base characteristic of experienced and competent constructivist educators. Additional studies might include; what could be done to promote more change with upper grade level teachers, which elements of the systemic change process were most critical for effecting changes in teachers views about the adequacy of the curriculum and indeed about the change in instructional practices.

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FIFTH GRADE STUDENTS' PERCEPTIONS ABOUT SCIENTISTS AND HOW THEY STUDY AND USE SCIENCE

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Introduction

Studies assessing students' images of scientists (Krause 1977; Chambers 1983; Schibeci & Sorenson 1983; Fort & Varney 1989; Huber & Burton 1995; Finson, Beaver & Cramond 1995) have shown that students possess interesting stereotypic images of scientists. For example, students generally perceive scientists as being white males and view scientists as individuals who work alone in a laboratory. Chambers (1983) and Schibeci and Sorenson (1983) found that as young children progress through successively higher grade levels, their images of scientists become more and more stereotypic until they reach fifth grade. At this time, their stereotypic image of a scientist appears to be fully developed.

The most common technique used to assess students' images of scientists has been the Draw-A-Scientist Checklist (DAST-C), developed by Chambers (1983). In using DAST, investigators ask students to reveal their image of a scientist through a drawing. To provide a reliable and efficient format for analyzing students' drawings, Finson, Beaver, and Cramond (1995) developed the Draw-A-Scientist Checklist (DAST-C). Each item on the DAST-C represents a stereotypic characteristic derived from reviews of literature relating to students' images of scientists. During the analysis of a student's drawing, the more items "checked" on the DAST-C, the more stereotypes appear on the student's drawing. Although the DAST and the DAST-C are useful; tools in gaining insight into students' concepts of scientists, Finson, Beaver, and Cramond (1995) identify two cautions in the use of these instruments:

> Maoldomhnaigh and Hunt (1989) reported that students may posses more than one definition of the word scientist, and this may results in students drawing different images at different

> times without having their perceptions changed by a particular treatment. Additionally, Maoldomhnaigh and Mhaolain(1990) found that changing the wording in directions given to students can alter the types of drawings produced. Such results underscore the importance of having a standardized procedure, including standardized instructions, to follow when administering the DAST. In addition, although the DAST-C appears to yield results similar to those obtained through structured interviews (indicating it accurately assesses the students perceptions of scientists), it may fail to elicit all the richness of data possible through interviews. (p.204)

The Portrayal of Scientists in the K-12 Curricula

Since the early 1970's, concerted efforts have taken place to present inclusive images of scientists and to show how they engage in the scientific enterprise. For example, in K-12 science programs, women and ethic minority groups are depicted as having active roles in science. In features like "Ask a Scientist" in *Addison-Wesley Science*, scientists are portrayed as "regular people" who dress in everyday clothes and are able to communicate about their scientific activities to children (Barman, et.al. 1992). Science related careers are highlighted in *Destinations in Science* (Brummett, et.al. 1995), *Discover the Wonder* (Heil, et.al. 1993), and *MacMillan/McGraw-Hill Science* (Atwater, et.al. 1993) to show students that "doing science" occurs in a variety of occupations. In addition, some science programs have incorporated features that show students how science occurs in their everyday lives. For example the "Back Home" feature from *Destinations in Science* (Brummett, et.al. 1995) invites students to use their home or neighborhood to study science and the "Technology and Society" feature in the *MacMillan/McGraw Hill Science* (Atwater, et.al. 1993) shows students how science knowledge and the applications of science relate to the everyday life of themselves and their family members.

The way students studied science has also been an area of concern for science educators and curriculum developers. The main issue has been to find ways for students to be "doing" science rather than just reading about it (Kahle 1992). Therefore, most recent K-12 science materials have included a variety of activities that encouraged students to engage in the same processes that scientists use. In these activities, students describe objects and events, ask questions, construct explanations of natural phenomena, test those explanations, and communicated their ideas to others.

Procedures

Because of the concerted efforts since the 1970's to provide students with a realistic image of scientists and how they go about "doing science," we are interested in addressing three specific questions related to the way students view science. Specifically, we will focus on the following questions: (a) What are the current images that students have of scientists? (b) How do students perceive they study science in school? and (c) Do students perceive they are using science outside of school? To address these questions, we devised a protocol that incorporated the current methods of DAST, some techniques to take into account the cautions suggested by Finson, Beaver, and Cramond (1995) which relate to using a standardized procedure and structured interview questions, and procedures that we felt would further enhance our ability to understand the students' perceptions of scientists and science.

An initial concern that we had about DAST was related to asking students to make a "forced choice." If you ask students to draw a scientist, does this force them to make a choice between a male or female? Or, if you asked students to draw two scientists, would this provide them with the freedom to depict both sexes? To answer this question, we randomly selected two groups of ten fifth grade students. Each group had an equal number of boys and girls. Group A was asked to draw two scientists doing science while Group B was asked to draw one scientist doing science. In Group A, 7 students drew two male scientists, 2 students drew a male and female scientist, and 1 student drew 2 female scientists. In Group B, 7 students drew a male scientist and 3 students drew a female scientist. Because the drawing of two scientists took each students twice as long to complete as the drawing of one scientist and because there appeared to be no major differences in the results of groups A and B, we decided to develop our protocol with students drawing only one scientist.

We also wanted to provide students with an opportunity to draw scientists from different racial backgrounds. Therefore, we provided each student with a set of colored pencils or crayons before they were asked to draw a scientist.

Each student was given the following directions and asked questions individually. Even though each student was asked a set of standard questions, each interview session was informal enough to allow the investigator to gain additional information about the students' drawings and to clarify any of their responses. The responses were audio-taped and later transcribed for further analysis. The set of directions and questions used in each interview session are:

1. Will you please draw a picture of a scientist doing science? When you are finished, will you please explain your drawing?
2. On another piece of paper, will you please draw a picture of yourself doing science in school? When you are finished, will you please explain your drawing?
3. Can you think of some ways you use what you learn in science outside of school?

Sample

One hundred seventeen fifth grade students (57 males and 60 females) from the midwestern and southwestern parts of the United States were chosen for this study. Eighty-seven of these students came from one private school and two public schools in a large midwestern city. The remaining 30 students came from a private school in a large southwestern city. The students enrolled in the private school in the midwest were primarily from middle to upper income families while the students from the private school in the southwest were mostly from middle income families. The two public school from the midwest contained students primarily from low to middle income families. In terms of ethnic background, 73 students were Caucasian, 40 students were Afro-American, and 4 students were of Asian descent.

Analysis

The students' drawings of scientists were analyzed using the DAST-C. Each drawing was rated for specific stereotypic images and additional information obtained from the student interviews was compiled and reviewed (table 1).

Table 1

Students' Stereotypic Images of a Scientist (N = 117)

Common stereotype	Students responding (in %)
1. Scientist Wearing a Lab Coat	26
2. Scientist Wearing Eyeglasses	26
3. Scientist With Facial Hair	5
4. Symbols of Research Displayed (e.g., instruments, lab equipment, etc.)	85
5. Symbols of Knowledge (e.g. books, clip boards, pens in pockets, etc.)	15
6. Technology Represented (e.g. telephone, TV, computers, etc.)	11
7. Relevant Captions (e.g. formulae, classification, "eureka", etc.)	7
8. Male Gender Only	80
9. Caucasian(s) Only	93
10. Scientist in Middle Aged/Elderly	10
11. Scientist has Mythic Stereotypes (Frankenstein creatures, etc.)	15
12. Indications of Secrecy (Warnings of "private," etc.)	2
13. Scientist is Working in Lab	90
14. Indications of Danger	11

15. Open comments related to dress items, neckties, hair style, smile/frown, etc.	
• Depicted scientists wearing regular clothing (e.g., bluejeans, T-shirt)	20
• Drew the scientist with a smile	23

The drawings of students doing science were grouped into two main categories: (1) those who pictured themselves as passive learners such as reading about science or taking notes at a desk and (2) those who saw themselves as active learners (table 2). Additional information obtained from interviews was also compiled and analyzed.

Table 2

Students' Perceptions of "Doing Science" in School (N = 117)

Activity represented	Students responding (in %)
1. Seated at Desk Reading or Taking Notes	56
2. Participating in Activity	27
3. Other (looking for insects, leaves, plants, or rocks outdoors)	17

Data related to students' perceptions about using science outside of school were gathered from the interview transcripts. These data were categorized into four main groups: (a) students who think they can use science but are unsure how, (b) students who only see themselves using science by repeating activities from school, (c) students who could generalize the use of science knowledge and processes to everyday situations, and (d) students who did not see any use of science outside of school (table 3).

Table 3

Student Perceptions of Using Science (N = 117)

Category	Students responding (in %)
1. Never Use Science Outside of School	26
2. Activities are Extension of School Assignments	60
3. Did Use Science But Not Sure How	5
4. Could Generalize Use of Skills and Knowledge of Science to Everyday Situations (e.g., solving problems, making observations and inferences, animal and plant identification, prediction weather, and care for plants and pets)	9

Results

Perceptions of Scientists

As shown in table 1, the students in this study had similar images of scientists to those revealed in previous studies (Chambers 1983; Fort & Varney 1989; Finson, Beaver, & Cramond 1995; Huber & Burton 1995). Generally, the students perceived scientists as being white males who do their work in some type of laboratory.

A few other items worth noting about the students' drawings of scientists are related to the scientists' clothing and their facial expressions. Scientists wearing regular clothing such as bluejeans and t-shirts are depicted by 20% of the students while 26% pictured the scientist in a lab coat. In regard to showing any facial expressions on the scientists, most of the students depicted scientists with no expression. However, 23% of the students did draw scientists with smiles on their faces. When asked to explain this aspect of the drawing, the students generally indicated that the scientists enjoyed doing their work.

Perceptions of School Science

When students were asked to draw a picture of themselves doing science in school, 56% drew themselves at desks either reading a science book or taking notes. When asked about their drawings, several of the students said that they usually sit at a desk and read their science book. However, these students also indicated that they would prefer to do some type of activity during science. Doing some type of science activity was depicted by 27% of the students while 17% drew themselves outdoors looking for insects, leaves, rocks, or plants.

Perceptions About Using Science Outside of School

The majority of the students (60%) viewed the use of science outside of school as an extension of their school experiences. Students cited specific school activities that they did at home such as mixing vinegar with baking soda. Several students stated that they were able to help one of their younger siblings with their science homework because they had been given similar assignments. It was felt by 26% of the students that they never use science outside of school and 5% thought they probably use their science knowledge and skills outside of school, but they were unsure as to how they use the knowledge or skills.

A total of 9% of the students were able to connect the skills and knowledge they gained from science to everyday activities. For example, these students cited how they use problem solving, making observations and inferences, identifying small animals and plants, predicting weather, and caring for plants and pets in their everyday lives.

Discussion

Although steps have been taken by curriculum developers and science educators in the last few decades to highlight women and minorities in science, most of the students in our sample perceive scientists as white males who practice science in some type of laboratory. This points to a continued need to search for ways to show K-12 students that scientists are represented by both genders and are from a variety of ethnic backgrounds. In addition, scientists should be portrayed as everyday people. Therefore, teachers need to be encouraged to use the special features in science textbooks that highlight science careers, depict scientists as everyday people who are capable of sharing their work with non-scientists. Resources, like *Dragonfly* (Project Dragonfly 1996), could also help teachers present students with an inclusive image of science and scientists. *Dragonfly* is a publication in which students interview scientists and publish the procedures and results of studies they have conducted. In addition, this magazine highlights the work and daily lives of scientists.

The most recent K-12 science curriculum programs include activities to engage students in "doing science." However, a large number of students in our sample perceive their school science experience as either a reading exercise or a time to listen to someone lecture about science. The *National Science Education Standards* (National Research Council 1996) has explicit recommendations about teaching science as a process of inquiry. Teachers need professional development which provides dialogue and concrete examples designed to help them put these recommendations into classroom practice.

Videotapes featuring scientific expeditions and investigations would present scientists in a dynamic mode. Inviting women and minorities to talk with the class about how they learn about and use science would offer opportunities for students to broaden their ideas about scientists on a more personal level. Building on these experiences, pointing out the scientific contributions by females and minorities would continue to broaden student perspectives. The historical sequence in the development of our understandings about the way things work would help students gain an appreciation for the personalities of scientists as "real people."

Our findings in this study indicate that most students do not see a connection between what they learn in science and how it can be applied to their everyday lives. Students need to be presented with concrete examples that demonstrate the connection between school science and what they do outside of school. For example, teachers could engage students in activities that show them how specific skills like observing, measuring, and classifying are used in everyday activities (Mercier & Ostlund 1996). Students could be encouraged to make collections of things such as rocks, leaves, insects, etc. in order to discover patterns and to develop classification skills.

Engaging students in product testing is an effective strategy for learning how to use the skills of science. As students conduct a "fair test" for various products they will learn how to control variables in an investigation. This may help make science more relevant for students. Additionally, involving teams of students in long term investigations will help them get a feel for the work that scientists do. These projects simulate what scientists do, e.g., working together to formulate a question, making observations, gathering data, drawing conclusions, sharing and challenging conclusions drawn from data, and finally trying to reach a consensus. Additionally, making connections with math and communications creates a realistic view of doing science.

Science classes could also incorporate live communication with scientists. For example, Internet connections can involve classes around the world in conducting research and sharing data on phenomena such as the pH of rain. The Jason Project is another way students can engage in doing science with active scientists.

Final Note

The next step is to plan and implement a pilot program using some of the ideas presented above. Since assessment often drives the curriculum, if students' ideas about scientists and how they use science everyday is evaluated, teachers will be more likely to employ strategies to increase realistic perceptions. The information that we obtained in this study has been limited to a few schools in the midwest and southwest. We encourage others to use the protocol discussed in this paper to gain insights about how students in different parts of the United States perceive science and its relevancy to them. We also believe that the protocol discussed in this paper should be used on a continual basis by teachers to collect information about how their students' views regarding science change over time. These data would provide valuable feedback to teachers regarding whether students are developing a realistic perception about science and its usefulness to them. This information could serve as an evaluation tool for teachers to assess the effectiveness of their science instruction.

For a complete description of the protocol used in this study, please refer to: Barman, C. How do students really view science and scientists? (1996) *Science & Children*. 34 (1): 30-33.

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A UNIVERSITY GRANT PROJECT ON SCIENCE EDUCATION FOR STUDENTS WITH DISABILITIES: TEACHING ELEMENTARY SCIENCE IN INCLUSIVE CLASSROOMS

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Students with disabilities are now being integrated into general education classrooms. Elementary teachers are expected to teach these students all academic areas, even though they have received limited training in working with students who have disabilities. Many elementary teachers have not had professional development experiences in either science content or science methods.

The science learning needs of many students with disabilities are not being met in regular classrooms, as evidenced by the failing or borderline passing grades. Yet science has been identified as one of the most valuable subjects that can be taught to students with disabilities. Advantages of science include the concrete, hands-on learning activities; less focus on language skills such as reading and writing; high level of group interaction and participation; and the promotion of interest and inquisitiveness.

There is a need to focus on the training of teachers to adequately prepare them cognitively and affectively to accept and instruct students with special needs. An additional need is to involve more elementary teachers in science so that they are able to engage all students in science experiences. This program is designed to fill the need for instruction for preservice elementary teachers in science education and special education.

Description

Teaching Elementary Science in Inclusive Classrooms is a science education program at The University of Texas at Brownsville designed to prepare elementary teachers to teach science to students with disabilities in inclusive classrooms. It is funded by the National Aeronautics and Space Administration (NASA), the Lyndon B. Johnson Space Center in Houston. Program participants are preservice teachers enrolled in two undergraduate courses: Teaching Children with Disabilities in Inclusive Settings and Teaching Science to Special Populations.

Teaching Children with Disabilities in Inclusive Settings presents information on inclusive education for students with disabilities. Characteristics of various handicapping conditions are examined as well as appropriate instructional modifications related to science. The participants are taught adaptations to use in teaching students with disabilities so that they may obtain and use scientific information. An emphasis is placed on the contributions to the field of science made by individuals with disabilities and particularly those from minority backgrounds. Participants gain an appreciation of the untapped abilities of future South Texas scientists.

Teaching Science to Special Populations includes information on teaching inquiry science in classrooms of diversity. Topics include adaptations and modifications of science curricula, activities to engage all learning modalities and multiple intelligences, cooperative groups in lab investigations, planning for safety in the science laboratory, and strategies and techniques for disruptive behaviors. Participating teachers take part in hands-on science activities designed for students with disabilities, and assist elementary students in the design of science projects. The course includes a field experience component during which students work with cooperating teachers to teach science to students with disabilities in inclusive classrooms.

During the two courses, participants develop science instructional modules for use in public schools. The modules include science activities for elementary school students with learning, visual, hearing, orthopedic, mental and emotional disabilities. In addition, participants implement interventions using modifications in science lessons for students with disabilities, and they document their efforts in case studies. The case studies and science modules are presented and discussed during a panel presentation at the University at the conclusion of the year-long program.

Objectives

The objectives of this project focus on helping preservice teachers develop a knowledge base about individuals with disabilities and about best practices in meeting the needs of students with disabilities in the science classroom. The four project objectives are listed below.

1. To familiarize prospective teachers in elementary general education to the characteristics of students with disabilities.
2. To enable prospective teachers in elementary general education to develop adaptations and modifications of investigations in science to facilitate the inclusion process of students with disabilities.
3. To develop science modules for use in public schools, on teaching elementary school science to students with disabilities in inclusive classrooms.
4. To create a mechanism to disseminate the model for this program and its products.

Special Education Categories

For those not familiar with special education, the categories of disabilities and terminology associated with these disabilities can seem overwhelming. The various categories of disabilities and impairments are summarized in this section.

Learning Disabilities

A learning disability refers to a disorder in one or more of the basic psychological processes involved in understanding or in using language (spoken or written) which may manifest itself in an imperfect ability to listen, think, speak, read, write, or do mathematical calculations. The term includes perceptual handicaps, brain injury, minimal brain dysfunction, dyslexia, and developmental aphasia. The term does not include children who have learning problems which are primarily the result of visual, hearing or motor handicaps or mental retardation, or emotional disturbance, or of environmental, cultural or economic disadvantage.

Speech or Language Impairments

Speech disorder

A *speech disorder* is an impairment of voice, articulation of speech sounds, and/or fluency. These impairments are observed in the transmission and use of the oral symbol system. A *voice disorder* is defined as the absence or abnormal production of vocal quality, pitch, loudness, resonance, and/or duration. An *articulation disorder* is defined as the abnormal flow of verbal expression, characterized by impaired rate and rhythm which my be accompanied by struggle behavior.

Language disorder

A *language disorder* is the impairment or deviant development of comprehension and/or use of a spoken, written, and/or other symbol system. The disorder may involve (1) the form of language (phonologic, morphologic, and syntactic systems), (2) the content of language (semantic system) in any combination.

Mental Retardation

Mental retardation refers to substantial limitations in present functioning. It is characterized by significantly below average intellectual functioning, existing concurrently with related limitations in two or more of the following applicable adaptive skill areas: communication, self-care, home living, social skills, community use, self-direction, health and safety, functional academics, leisure, and work. Mental retardation manifests before age 18.

Serious Emotional Disturbances

This term refers to a condition with one or more of the following characteristics displayed over a long time and to a marked degree that adversely affects a student's educational performance:

- An inability to learn that cannot be explained by intellectual, sensory, or other health factors
- An inability to build or maintain satisfactory interpersonal relationships with peers and teachers
- Inappropriate types of behavior or feelings under normal circumstances
- A general pervasive mood of unhappiness or depression
- A tendency to develop physical symptoms or fears associated with personal or school problems

The term includes children who are schizophrenic but not children who are socially maladjusted, unless they are seriously emotionally disturbed.

Multiple Disabilities

Multiple disabilities means concomitant impairments (such as mental retardation-blindness, mental retardation-orthopedic impairment), the combination of which causes such severe educational problems that they cannot be accommodated in special education programs solely for one of the impairments. The term does not include deaf-blindness.

Hearing Impairments

This disability refers to an impairment in hearing, permanent or fluctuating, that adversely affects a child's educational performance but which is not included under the definition of deafness.

Orthopedic Disabilities

Orthopedic disability means a severe orthopedic impairment that adversely affects a child's educational performance. The term includes impairments caused by congenital anomaly (clubfoot, absence of some member), impairments caused by disease (poliomyelitis, bone tuberculosis) and impairments from other causes (cerebral palsy, amputations, and fractures or burns that cause contractures).

Other Health Impairments

Other health impairments refers to having limited strength, vitality, or alertness due to chronic or acute health problems such as a heart condition, tuberculosis, rheumatic fever, nephritis, asthma, sickle cell anemia, hemophilia, seizure disorder, lead poisoning, leukemia, or diabetes that adversely affect a child's educational performance.

Visual Impairments

Students with visual impairments represent a wide range of visual abilities. Consistent with IDEA, educators classify students with visual impairments by their ability to use their vision or their tendency or need to use tactile means for learning:

- Low vision describes individuals who can generally read print, although they may depend on optical aids, such as magnifying lenses, or other means to enlarge the size of the print. A few read both Braille and print. Individuals with low vision may or may not be legally blind but are able to use their visual sense for learning.
- Functionally blind describes individuals who typically use Braille for efficient reading and writing. They may rely on their ability to use functional vision for other tasks, such as moving through the environment or sorting clothes by color before washing them. Thus, they use their limited vision to supplement the combination of tactual and auditory learning methods.
- Totally blind describes those individuals who do not receive meaningful input through the visual sense. These individuals use tactual and auditory means to learn about their environment.

Deaf-Blindness

Individuals with deaf-blindness may have diverse combinations of vision and hearing impairments with normal or gifted intelligence, or they may have additional mental, physical, and behavioral disabilities. Because these individuals do not receive clear and consistent information from either sensory modality, a tendency exists to turn inward to obtain the desired level of stimulation. The individual may appear passive, nonresponsive, and/or noncompliant. Students with dual sensory impairments may not respond to or initiate appropriate interactions with others and often exhibit behavior that is considered socially inappropriate.

Traumatic Brain Injury

Traumatic brain injury refers to an acquired injury to the brain caused by an external physical force, resulting in total or partial functional disability or psychosocial impairment, or both, that adversely affects a child's educational performance. This term applies to open or closed head injuries resulting in impairments in one or more areas, such as cognition; language; memory; attention; reasoning; abstract thinking judgment; problem-solving; sensory, perceptual, and motor abilities; psychosocial behavior; physical functions; information processing; and speech. The term does not apply to brain injuries that are congenital or degenerative, or brain injuries induced by birth trauma.

Autism

Autism describes a developmental disability significantly affecting verbal and nonverbal communication and social interaction, generally evident before age 3, that adversely affects educational performance. Other characteristics often associated with autism are engagement in repetitive activities and stereotyped movements, resistance to environmental change or changes in daily routines, and unusual responses to sensory experiences. The term does not apply if a child's educational performance is adversely affected primarily because the child has a serious emotional disturbance

General Guidelines for Working with Students Who Have Disabilities

There are numerous special education texts which elaborate on each of the disabilities, and make recommendations on how to teach students with each of these disabilities. However, the inclusive classroom may include many students with different disabilties, as well as students of various achievement levels who are not labeled "special education." The general education teacher needs to know how to teach a class of students that is composed of students on these various ability levels and that have many distinct needs. Ten useful suggestions are presented below.

1. Empower the student to be an active participant in all classroom and school activities.
2. Do things with, instead of for, the student when he or she needs assistance.
3. Include the student in conversations. Never talk about the student in front of her or him.
4. Consider the age-appropriate expectations of classmates. Treat the student as you would her or his classmates.
5. Develop ways for classmates and teachers to include the student. Be a model on how to do this.
6. Be a part of the class. Work with all students.

7. Know, follow, and enforce classroom rules.
8. Watch classmate and teacher reactions to a potentially disruptive student. Respond accordingly and problem-solve on the spot.
9. Point out successes and positive changes for all to celebrate.
10. Be friendly but firm. Maintain consistency in your expectations and in your responses.
11. Adapt and modify materials and procedures to the special needs of each students. Try to incorporate into your lessons activities that engage all learning modalities --visual, auditory, tactile, and kinesthetic.
12. Break complex learning into simpler components, moving from the most concrete to the abstract.
13. Have students copy assignments for the week into a folder kept in their notebooks.
14. Plan active learning activities that help the students connect what is being learned with their real world.

Components of Effective Inclusion Programs

Our experiences suggest that there are four necessary components to successful inclusion programs in teacher education:

- Collaboration between general educators and special educators.
- General adaptations for working with students who have disabilities.
- Specific adaptations, as identified on the Individualized Education Plan (IEP).
- Empathy, beginning with an awareness of who the students are, as well as their strengths and limitations.

KNOWLEDGE AND INCIDENCE OF DOMESTIC VIOLENCE AMONG ELEMENTARY SCIENCE METHODS STUDENTS

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Introduction

Science does not exist in a vacuum. Indeed, as proponents of the Science, Technology, Society focus for science education have said for many years, science education is embedded in the fabric of society. No one in the science education community would argue that science education should no longer be presented as a discreet set of memorizable facts and concepts. Most would now agree that the best science education utilizes both the prior experiences and cultural contexts of the learners. Equally as important is that science educators view their preservice teachers in exactly these same constructivists contexts: the lived experiences of those elementary science methods students influence their understanding of what is taught more than any other single factor.

Feminist researchers have reported for years that female students feel alienated in most science courses. Efforts begun two decades ago that sought to increase the number of women who become scientists have not brought the desired changes. A partial solution may be to teach from the experiences and needs of the female student population. Clearly, the statistics that follow on domestic violence as well as the results of this survey show that large proportions of women and girls encounter domestic violence at some time in their lives, including those women who become teachers. Domestic violence is, above all, a health issue for women. The results of this study portend that twice as many women who are enrolled in elementary preservice science methods courses than the national average have experienced domestic violence. This result is alarming and demands that further research into the matter be conducted; curriculum may need to be developed that addresses the health aspects for all women in teacher education courses as well as for their future K - 12 students. The National Association for Children of Alcoholics (NACOA, 1986;

Allen, 1989) has developed such materials to address the needs of elementary education teachers and their students; NACOA's model can be used as a guide for curriculum development for teachers and children who experience violence in the home.

Multicultural science education has yet to confront curriculum development areas; that is, the topics selected as worthy of study--the content of courses--has yet to be colored by the multicultural lens. Melear (1995), however, has presented a multicultural framework for topics in biology that includes domestic violence, children of alcoholics, alcohol education, substance abuse, AIDS education, nutrition, prenatal care, disease prevention, contamination of water and environmentally associated diseases. Melear argued that some of these were topics of more importance to women and minority groups for the reason that women and minorities were more often the victims when, for example, domestic violence or alcohol abuse occurs.

It may come as a shock to science education readers of this paper that anyone would propose such a topic as domestic violence for inclusion in the teacher education curriculum. So great has been the stigma and invisibility of domestic violence and its victims that such a topic has never been raised in the experience of this science educator nor in the experience of those surveyed for this study. However, in view of constructivists' theoretical framework that undergirds science education research, the topic seems relevant. Also, in the view of James Rutherford, the director of the American Association for the Advancement of Science (AAAS) reform effort in science education, societal problems such as violence are factors in the practice of educators. Rutherford (1992) writes that "For many children, daily life is confusing, unstable, even dangerous. . . . Schools need to see that children escape those conditions for at least part of the day," (p. 5). Rutherford quotes chapter 14 in Science for All Americans, which explains that reform in education can improve America only if today's worst social problems are ameliorated. He does not say that educators should reform society. Yet he says that "curricula of the future must wrestle with the question of what balance to strike between school and community" (p. 5). Also, Rutherford says that we stand a better chance of improving America as educators make headway in "instilling in its graduates a commitment to health (personal, family, community, and environmental)" (p. 5).

Therefore, the topic of domestic violence is within the purview of scientific study for the impact it may have on science teaching and learning. The issue may be as important for teachers as for the children they teach. Allen (1989) reports that another group with history of abuse, children of alcoholics, are drawn to professions in which there is a care component, such as nursing and teaching. This phenomenon emanates from the dynamics of dysfunctional families in which some family members take over the responsibilities of the addicted or abusing partner. Children in these types of families adopt behaviors that they observe. We in the teaching profession may find an extraordinarily high representation of children of domestic abuse among our teacher education candidates just as Allen (1989) reported regarding children of alcoholics among the teaching profession. Indeed, this small study of two classes of candidates for teaching portends just that.

Another salient link of the topic of domestic violence to science education is that domestic violence is a factor in the health of women (Rosenberg & Fenley, 1991). Not only do women and girls constitute 50% of the K - 16 population, but more than 75% of all teachers are women. Also, women comprise up to 95% of elementary teachers. Therefore, the topic then is a gender issue because it has differential implications for women than men, especially in teacher education. The teachers in this study were all elementary education majors; they were surveyed in their science methods courses, required of all elementary education majors.

Both male and female children, however, are affected by domestic violence. A new report, Hidden Casualties, cited in NSTA Reports, 1996) finds that violence, both indirect and direct, has a considerable effect on learning ability and may limit cognitive ability and disturb physiological functioning. It is important for teachers to be able to detect when a child comes to school after witnessing an incident of violence. The constructivist framework demands that teachers understand the background and prior experiences of the learner.

Tobin (1994) acknowledges that "The histories that these students bring to their chemistry class are an integral part of the learning environment that has not often been the focus of researchers in science education" (p. 3). He suggests that in the chemistry class that he is observing that students have a problem with chemical addiction and their lives are touched by adults with substance abuse problems. He asks, "Why can't the curriculum extend to investigations of the problems that afflict the lives of these students?" (p. 3) And, he states that "It is clearly possible to develop courses that are rigorous and that intersect with the lives and interests of students," (p. 3). It is not that teachers are to be the designated social worker to intervene in a situation. Tobin's population is described in respect to sociocultural factors, such as low family income, low level of employment of parents, high incidence of students from single-parent homes, and a high proportion of students from homes where English is not a native language. Domestic violence is not localized to just these sociocultural factors, however.

The point is that if the statistics on domestic violence are to be believed and if the results of this study portend the size of the "iceberg," this is a problem that affects many women and children. A societal problem that affects a large number of children needs to be acknowledged and addressed by the professional education community. Because domestic violence is an issue of women's health (also children's well being), it is an issue for science educators to study. Domestic violence is a topic worthy of research and curriculum development because elementary teachers in most schools teach all subjects. There are no health educators in most elementary schools; even if there were, science and health go hand-in-hand in importance in the lives of children. All of the preceding argument is for inclusion of domestic violence as a topic of sociocultural importance in science education.

When we examine the traditional science curriculum, we see topics that have been chosen by the members of the science community; historically that has been members of one group, white men. Matthews (1992) in fact reports a masculine bias in science. We do not have to decide how that bias is displayed; it is enough to note that if men, in general, select topics of study, frequently they have not chosen topics of interest to women. For example, in science research, we have the well-documented and unarguable examples of males as exclusive subjects in heart-attack studies. Even though more women die from heart disease than from any other ailment, women were not included in heart disease studies until the last decade. Selection of topics to study for science research has its complement in selection of science topics to present in a science class or for science education research. This paper suggests that through a multicultural lens, topics of importance for science curriculum development and science education research includes both domestic violence and substance abuse. The study that follows is the first attempt to bring the issue of domestic violence into focus in science education parlance.

Domestic Violence Literature Review

More than 3 out of every 100--or 1.8 million--women reported that they had been severely assaulted by male partners or cohabitants (i.e., they were punched, kicked, choked, beaten, threatened with a knife or gun, or had a knife or a gun used on them) during the preceding 12 months (Straus & Gelles, 1990, cited in Centers for Disease Control and Prevention, CDC, 1996). Stark and Flitcraft (1991) report that 20% of adult women in the United States--perhaps as many as 15 million women--have been physically abused at least once by a male intimate. Clinical data from health care settings indicate that abuse may be the single most important source of injury among women (more than three times as many injuries as that received in auto accidents); that abuse is rarely an isolated episode; and that abuse is largely neglected by health researchers, including those specializing in injury. The CDC (1996) reports that one-half of all injuries presented by women in health care facilities were the result of a partner's aggression.

Abuse data may in fact be grossly underestimated because the presence of physical abuse is reported four times more often when women are asked about it directly in interviews than when they respond to questionnaires (O'Leary, Vivian, & Malone, 1992, in CDC, 1996). Stark and Flitcraft (1991) point out that personal interviews with victims of domestic violence are rarely done.

Stark and Flitcraft (1991) define domestic violence as the category of acts under which spouse abuse and woman battering are normally defined. An operational definition of violence or spouse abuse must rely on an inclusive notion of violence by an adult regardless of the severity of injury inflicted or whether it involves injury, psychosocial problems, or simply fear. The central concern is future health risks; and the important differentiation is between an anonymous assault, mugging, or other street crime where further assault by the criminal is unlikely and assault by any social partner regardless of sex, age, marital status, or cohabitation. Clinically, in health settings, the definition of spouse abuse would include any act of force (including threats) for which social partners seek help.

Spouse abuse indicates concern for males as well as females and for situations in which both partners are equally abusive. Equally important is violence among gays, lesbians or adolescent heterosexual dating partners. While survey and other data exist to demonstrate the frequency of woman abuse, there are no survey data indicating that men view husband abuse as a serious problem.

Battering is a syndrome (Stark, 1979, cited in Stark & Flitcraft , 1991) that describes a range of problems following initial episodes of abuse. The battering syndrome includes a history of injury and often includes sexual assault, general medical complaints, psychological problems, and persistent help seeking. Women who are separated, divorced, or single are at the highest risk of battering. No process comparable to battering has been observed among abused men. This suggests that woman abuse (which leads to battering) is clinically distinct from mutual abuse, husband abuse, and the range of other tactics couples use to resolve conflicts. Woman abuse is a problem with an extremely low spontaneous-cure rate. Stark, Flitcraft, and Frazier (cited in Stark & Flitcraft, 1991) report that 85% of the women in their medical case load who have ever been abused remain at risk. Battering may be presented to health care providers through chronic and frustrated help seeking; nonspecific complaints of pain, injury during pregnancy, fear or anxiety associated with family conflict; isolation; and multiple psychosocial problems related to the stress of living in a violent home, including substance abuse, rape, child abuse, attempted suicide, and mental illness. The disproportionate risk of these problems among battered women appears primarily after the onset of abuse, which suggests that battering is the cause.

The model favored by Stark and Flitcraft (1991) to explain why battering occurs is the feminist gender-politics model, though they describe the interpersonal violence and the family violence models as well. The gender-politics model contends that violence in the family is merely a special instance of a pattern of male control that extends from dating relationships through parenting and marriage to economic life. Violence is an option some men choose when they feel their privileged access to scarce resources (like money or sex) is threatened by female independence or when women fail to fulfill perceived domestic responsibilities. Women do not stay in abusive relationships because of psychopathology on their part. Women stay in abusive relationships more because of fear, lack of emotional and economic support, interventions that blame them as victims, and because the absence of resources combine to make mere survival more practical than escape. Support for the gender-politics theory is compelling (Stark & Flitcraft, 1991). Clinical data implicate male violence and control as the source of abuse to women. Single, divorced, and separated women are actually at a greater risk of abuse than married women; and women are injured as frequently by dating violence as by marital violence.

Method

Students in two elementary science methods classes (N = 40) in a large regional southeastern United States university in the fall of 1995 were the subjects. The mostly all women (there were 4 men) were asked near the end of a class meeting to voluntarily and anonymously answer three questions regarding domestic violence. 1. What personal knowledge do you have of domestic violence? (If you are not sure if what you know is really abuse, please list it; and I can decide). 2. What knowledge, other than personal, do you have of domestic violence? 3. What can elementary teachers do regarding this issue? No discussion of domestic violence had occurred in the class that day; indeed, the topic had never arisen. All students in both classes willingly participated, some taking great pains to stay after class to complete rather lengthy answers.

Results

Table 1 shows that 18 (45%) of the students had personal knowledge of domestic violence.

Table 1. Personal Knowledge of Domestic Violence N = 40

	Number of Students	Percent
No knowledge	22	55
Knowledge	18	45

The following are sample remarks of students (S) from question 1:

S1: I know someone who is extremely cruel to his wife and children. He has been violent towards both. He destroy(s) articles in the how (se). He takes away privileges from his oldest son fo(r) no reason. He even threw away the child's comic books. Whatever brings anyone else pleasure he takes away. The children are withdrawn and fearful. Beneath the surface there is a burning hatred in the son. He has expressed a desire to kill his father.

S2: I know of a woman whose husband ass(a)ulted her, then claimed she hurt him. She was the one with bruises not him. This same man, who I had been married to, verbally abused me. He had me feeling I couldn't accomplish anything. He had to know where I went and how long I'd be gone, but he could do anything he wanted. He abused our children also. Physically he whipped excessively. Verbally they weren't any good no matter what they did.

S3: I worked with a woman last summer who was abused by her husband many times. She came to work with broken fingers, bruises, and other signs of abuse. My boss reported her husband for abuse, but I'm not really sure what was ever done to help her.

S4 Personal knowledge is that I was abused, threatened and very scared of an x-boyfriend. He would threaten to kill me if I did not do things. It got to the point where I was scared for my life to do anything, and the thing I wanted to do most is get away from him. At this point in my life I weight 125 pounds and was very attractive (very thin) and my nickname for 2 years was Chubby. Its funny now b/c he weighed about 230 pound and was 5'10" (FAT). I never thought that I would get in that type of situation b/c I have always been a very strong person. In this point of my life, I lost myself, my families support. . . everthing that was and is important to me. I got out of this relationship 2 years ago and about 1 1/2 yrs ago he came to my apt. here in Greenville, broke in & trashed it . . . so everyday basically I am still somewhat frightened by him in fear that I may see him, or he may call. It is not fun, but I have my mom back as my best friend & I have a lot of suport from the rest of my family & all of my great friends!! [The student drew a smiley face.]

S5: I have a female friend that almost died as a result of her husband's beatings. Also I have been told by many women that their husbands hit or slap them when he is angry or has been drinking. The manner in which they speak of this, suggest that they do not consider this domestic violence, but an occassional lapse in good judgement on his part.

S6: I have seen one of my goodfriends abused by her boyfriend. When they fuss, he would hit, kick, or push her. They finally broke up. My 2 little cousins were also thrown across the room by their stepfather. He said he threw them on the bed but they had severe bruises (age 15 mo. & 3 yr.).

S7: I have never been abused but I have worked at (the) Women's Shelter. The sites that I have seen will horify you. I have seen women & children so physically abused it was hard to tell exactly what they looked like.

S8: I just know my grandmother was made to do extra work around the house. She cooked, cleaned, took care of the many children, etc., even with everyone at home. This is a little of both physical and mental. She also received severe discipline.

Table 2 shows that of the eighteen, three (16.6%) were personally abused and 15 (83.3%) have friends or family who were abused.

Table 2. Nature of Personal Knowledge of Domestic Violence N = 18

	Number of Students	Percent
Personally abused	3	16.6
Friends or family abused	15	83.3

Table 3 shows the types of domestic violence experienced by the preservice elementary teachers who were personally abused. Two were physically abused and all three suffered verbal abuse.

Table 3. Types of Domestic Violence You Have Experienced N = 3

	Number of Students	Percent
Physical abuse	2	40
Verbal abuse	3	60

Table 4 lists the types of domestic violence experienced by friends or family of the preservice elementary teachers. Fourteen students (73.7%) listed physical abuse and five listed verbal abuse. The number of incidents is greater than the 15 who reported friends or family abused because in some cases both physical and verbal abuse was reported.

Table 4. Types of Domestic Violence Your Friends or Family Have Experienced N = 22*

	Number of Students	Percent
Physical abuse	14	73.7
Verbal abuse	5	26.3

*Some students listed both verbal and physical abuse

Table 5 shows knowledge sources other than personal about domestic violence of all 40 students. Most said they knew about domestic violence from the media, or they simply explained their understanding of domestic violence. Four students said that they had received education about domestic violence. Four listed the "O. J. trial" as their source of knowledge about domestic violence. One student left the question blank.

Table 5. What Knowledge other than Personal Do You Have About Domestic Violence? N = 40

	Number of Students	Percent
Media	16	40
Education	4	10
*Explanation	15	37.5
O. J. Trial	4	10
None	1	2.5

*Explained domestic violence but gave no sources

The following are sample responses to question 2:

S1: I know that domestic violence is usually about control issues. I also know that it happens often. The O. J. trial really brought out the whole domestic violence issue. I feel that it is something that needs to be addressed. [This response was from a student who has no domestic violence in her family but who knows someone who has been abused.]

S2: Domestic violence is any type of abuse be it verbal, physical, or mental from a spouse, parent, child, boyfriend, girlfriend, or friend. It is anything that can hinder your train of thought in such a way that it makes you scared or frightened of another human being. It is anything harmful (physically) that can hurt you by another person. [This was from one of the students who anonymously identified herself as having been personally abused.]

S3: I hear about it on the news all the time. It's definitely not rare. It's not regulated to just physical abuse.

S4: Domestic violence has become a very "hot" item on TV talk shows. It always amazes me how some women believe this to be love!

S5: There are many forms of domestic violence but I do not know every one. I do feel strongly on knowing most of them. Such as: striking someone with the fist or any object, always blaming others for your actions, pushing others (for no reason) using force. Some people think only bruises & scars are proof of violence but any [thing] physical such as hitting or verbal abuse is considered a form of domestic violence.

S6: O. J. I know it is a big problem in today's society. Men think they can beat their girlfriends and wives and get away with it. O. J. did!

S7: I've noticed recently with the O. J. Simpson case that women are not given much support or help from law enforcers. There are not a whole lot of laws that protect women from this abuse.

S8: Just the common knowledge--it occurs more than you would think--it is a terrible problem in our society.

S9: I can say I know what channels to turn to if a situation like this occurs[s] because of my education about this issue. This response may be the best we could hope for.

Table 6 displays the list generated by the preservice elementary teachers regarding what elementary teachers can do about domestic violence. Twenty-four (40.0%) said elementary teachers could teach about it. Seventeen (17) said elementary teachers can report it. Eight (13.3%) said they could show support (to students presumably). Ten (16.7%) said they could notice signs (10) and one (1.7%) said to administer a questionnaire.

Table 6. What Can Elementary Teachers Do Regarding Domestic Violence N = 40

	Number of Students	Percent
Teach about	24	40
Show support	8	13.3
Report	17	28.3
Notice signs	10	16.7
Questionnaire	1	1.7

The following are sample remarks regarding question 3:

S1: Teachers can keep their eyes open & be aware of signs of abuse. I don't think that teachers should try to deal with this alone. I think if they suspect abuse, they should call on the guidance counselor or psychologist to help evaluate the suspected victim. They must also be careful not to wrongly accuse parents of abuse. It is really a touchy issue.

S2: Elementary teachers can teach their students what real love consists of in the world. And be a friend so that students can be able to communicate their fears and anxieties to them. This area will fit well into "Character Education," that is not being taught in the school systems.

S3: Elementary teachers can teach about domestic violence in the classrooms. It can be explained simply as "this is wrong." If someone sees this happen, they need to let an adult know. Teachers should also watch students & see if they look abused.

S4: School teachers should be able to notice some problems w/children. All a teacher can do is support the child. If there is enough proof, I think they have to report it. The main thing to do is encourage the child, and let them know there is help.

S5: Look for signs from students that something may be going on at home and refer the children you suspect may be experiencing this to the counselor.

S6: Elementary school teachers should teach a limited amount of information concerning this issue. It all depends on what grade level and if they are ready for something of this nature. *I believe the teacher needs to make sure that she will be able to discuss this with her class before actually doing it* [italics added].

S7: I think the most important thing a teacher can do is make the child aware of what domestic violence is. It could be going on right in the very home, but if it is something that goes on all the time, the kids don't realize the harm. Teachers should report any scenes of any kind of abuse or violence to the *proper authority*!

S8: They can talk about domestic violence and let the children know that it is abuse, but that if it is happening it is not their fault. Let them know where they can go to receive help.

S9: Teachers should intervene to prevent or stop domestic violence. If it exists in a student's home life, the teacher should report it.

S10: Elementary teachers can enlight[en] children to at least be able to recognize and address such abuse. i.e.: Where do you go for help.

The following are sample remarks regarding teaching about domestic violence:

S1: Just giving a basic introduction to the issue. Also make the environment feel relax & easy so if the children want to confide in someone.

S2: We can teach students to recognize what it is.

S3: Bring the subject up in general during health class or have (a) book that may discuss this problem in the class. Having a speaker come in to address issues the class may have also gives children the feeling that they're not alone.

S4: They can teach kids more about it & how to prevent abuse.

S5: Hard issue--teaching that violence/hitting is wrong is fine, but when kids see it happen at home, they may interpret it as OK.

S6: Talk about the subject and let children know that it is something that they can talk about to a counselor or someone in the school.

S7: Elementary teachers can talk to children and explain what domestic violence is. If any children want further information, they should be referred to a counselor.

S8: Teachers can teach students that fighting and violence is never an option. Especially the boys. Teach respect for others.

S9: Elementary teachers need to be cognizant of "signs" that children are living with a disfunctional family. Children who are scared to participate in class discussions, withdrawn into a shell, fear authority, etc. should be monitored closely, and social services via the principal made aware of the situation. Love, kindness, and patience are needed until the problems can be resolved.

S10: Elementary teachers can try to produce a trusting atmosphere wherein students are comfortable sharing in a journal any problems or feelings they have. Most students will not tell, but good teachers will pick up on hints that something may be wrong. Then, the teachers should refer the student to the school psychologist.

S11: Teachers can educate people how to deal with this issue--if they are the victims, or if they know that a friend is in trouble. Also, teachers can instill good values & self esteem to lead to healthy-minded individuals.

Conclusions

More than twice as many of the preservice teachers reported in this questionnaire format that they had personally been abused by a former male intimate than the national average (Centers for Disease Control and Prevention, 1996). Physical abuse may be occurring among the preservice teachers to a much higher degree than twice the national average because of two other factors. One is the research of O'Leary, et al. (1992) which showed that personal interviews result in four times as many reports of abuse than questionnaire formats, as was used in this study. In addition, and alarmingly so, a well known phenomenon in social work is that when a person presents to a helping professional, they will frequently mask what is happening to them by saying "I have a friend who....." In this study of elementary education preservice teachers, five times as many (N = 15) of them reported that a friend or family member had been abused as they themselves reported personal abuse (N = 3). Finally, 40% of these preservice elementary teachers in science methods recommend that elementary teachers teach about domestic violence in the classroom, while only 10% reported that they themselves received their knowledge about it through education.

Clearly there is cause for concern for elementary preservice teachers if this small study is indicative that (at least) more than twice the national average of incidence of domestic violence occurs among them. In addition, there is a glaring gap in the role education has played in the knowledge that these (mostly) young women have about domestic violence and the role of education they feel elementary teachers could play. Whereas only 10% of these preservice elementary teachers report receiving what knowledge they have about domestic violence in an educational setting, 40% report that elementary teachers can provide that education. Clearly, again, there is a role for curriculum development in this health care area for women and girls.

One model for curriculum development exists that could be used as a guide. The National Association for Children of Alcoholics (NACOA) has developed numerous teaching units, video, lesson plans, and materials for elementary teachers in the last decade. The NACOA realized that children of alcoholics were "forgotten children" as described by Cork (1969) in a book by that name. Frequently, but not always, substance abuse is a factor in domestic violence.

Violence in the presence of children is so traumatic, and may affect their learning to such a degree, that a separate training program and curriculum for teachers needs to be developed. We are just beginning to realize the prevalence of violence in our society; that is, many of us in education were removed from the scourge of the violence that today is present even in our schools. Those of us who hold the curriculum development keys should open the door to the discussion of violence in terms of the health of women and children. All of us know and have known that no learning can occur in the absence of safety; that is the bottom of the Maslow psychological needs model we learn as beginning teachers. Yet, none of us, like all the rest of society, wants to acknowledge the reality of the presence of violence among us, as indicated by reports (Allen, 1989) from the very teachers that we engage to study with us daily.

Constructivists cannot ignore domestic violence just because it has been ignored in the past; we cannot begin to address the lived experiences of our teacher education students if two times the national average of them are or have experienced violence in their lives without acknowledging it in some way. Constructivists cannot ignore it because there is a stigma attached to even talking about it. Feminist theorists say that something has to be named to remove it from invisibility. This paper is a wake-up call that the issue of violence among teacher education candidates deserves a response from education researchers. Because health issues of women are legitimate topics of study in science, science education researchers should be involved in these curriculum development and research efforts. Finally, there are personal empowerment issues which surround all issues of abuse. The reform efforts in education are replete with calls for teacher empowerment. Perhaps personal empowerment should be given some attention before teachers are urged to change their practice. The data here suggest that many teachers may have far more urgent issues to address in their personal lives than those of classroom practice.

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FACING THE CHALLENGES: FURTHER DISCUSSION OF THE FACTORS INFLUENCING THE SUCCESSFUL IMPLEMENTATION OF PROFESSIONAL DEVELOPMENT SCHOOLS

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In 1986 the Holmes Group set out to: change the way they educate teachers, help construct a true profession of teaching, cooperate with school people in inquiry that transforms the schools, and restructure their own institutions to achieve these ends. Those of us involved in the Kansas State University - Manhattan-Ogden Professional Development Schools believe these are powerful goals for the improvement of schooling and teacher preparation. We also believe such endeavors are inherently difficult. In addressing these goals for mutual reform and improvement, several challenges have emerged. These challenges are related to the changing relationships between schools of education and school districts which are a natural consequence of implementing Professional Development Schools.

Professional Development Schools

The Professional Development School (PDS) is a key vehicle for creating communities of learners for the continuous development of our educational system. The PDS involves students, parents, preservice and inservice teachers, administrators, school board members, university faculty, and community representatives as educational stakeholders and members of the PDS community of learners. The PDS philosophy requires all such educational stakeholders to engage in inquiry and reflective practice to discover how to develop and maintain effective educational systems that support educational excellence and equity (Holmes, 1990; Richardson, 1994). The Holmes Group has defined PDS as regular schools working in partnership with a university to develop and demonstrate: fine learning programs for diverse students; practical, thought-provoking preparation for novice teachers; new understandings and professional responsibilities of experienced educators; and research projects that add to all educators knowledge about how to make schools more productive (Holmes Group, 1990).

The PDS is much more than a collection of people in a building. "It entails an attitude, a perspective, a professional predisposition that releases educators to share what they know and to improve the teaching of students and the preparation of future educators. It involves a willingness to ask questions about old habits and new trends and to suggest different ways of reaching old and new goals. Ultimately, the Professional Development School embodies a bent toward doing whatever is necessary to ensure that all children and youth become engaged learners under the tutelage of well-prepared teachers" (Richardson, 1994, p. 4).

Six elementary and one high school PDS have been identified within the Manhattan-Ogden School District based on this vision. Currently, we are expanding our PDS model to include two local middle-schools and two additional elementary schools in neighboring rural and urban cities. All our PDS were established on the premise that education must be viewed as a continuum from preschool through university and that significant improvement in one part of this system is not likely without improvement throughout. As educators we cannot expect improvement in K-12 schools until we improve the preparation of teachers and administrators; but, we cannot sustain even the best teachers and administrators until we have effective school systems.

Our PDS model is based on the belief that teacher preparation and school reform are the joint responsibility of institutions of higher education and school systems. PDS participants have acknowledged that teacher preparation involves all groups of professionals who in any way touch the educational lives of teachers. Our aim is to create new roles for all participants to enhance the professional involvement of educators. This diversification of roles and responsibilities is a vital component of educational empowerment.

We are implementing this belief by utilizing teachers, administrators, and faculty, as co-planners of courses and field experiences, seminar leaders, university co-instructors, evaluators, and supervisors and mentors of student teachers. Teachers, administrators, and faculty are jointly involved in school improvement efforts, curriculum development and program evaluation, professional development activities, and collaborative research projects.

Teacher preparation is an extremely complex process which must be viewed as a continuum of career-long experiences which mold and shape the ever changing behaviors of the classroom teacher. Our PDS have permitted us to restructure our teacher preparation from this complex, holistic perspective as opposed to disjointed, incremental reform efforts. The PDS facilitate systematic field experiences within realistically complex environments. These experiences have become a unifying feature of our students' education by integrating content and pedagogy and providing a sense of relevancy for their studies.

We intend for our PDS to be sites where teachers, students and university faculty create new knowledge and try-out, evaluate and revise practices. Our PDS have become living laboratories for study, observation, experimentation, and extended practice. We are researching new instructional strategies, curriculum materials and teacher preparation techniques under a variety of working conditions. Our intention is to explore how children learn, how teachers learn and how schools improve. Professional development opportunities offered within PDS have been designed to provide educators with the knowledge, skills, attitudes and resources to empower them to create teaching and learning environments to meet the needs of an increasingly diverse student population. Examples of such opportunities are school-based seminars and study groups where future and practicing teachers reflect on their teaching and learning with peers, administrators, and university faculty.

Ultimately, PDS should exemplify the most current and best practices education has to offer. Classroom experimentation has included action research projects and "innovations in action". These experiences with collaborative inquiry have involved pilot testing and field testing new curriculum, technology, innovative teaching, and assessment techniques. Action research projects have been conducted to examine educational equity, parental attitudes, school change, and various indicators of school quality. Examples of "innovations in action" include: developing non-routine mathematical problem solving curricula; thematic teaching; peer coaching; team teaching; multi-age classrooms; and, alternative assessment strategies including authentic assessment, portfolios, non-graded report cards, and student-lead parent conferences.

This climate of experimentation and risk taking has also extended to the university where faculty are taking on new roles and trying out new practices. This has helped to create an active problem-solving mentality and a shared commitment to improving education at all levels.

The fundamental purpose for our PDS is to capitalize on the collaborative inclinations, experiences, and needs of the many educational partners in our community to demonstrate how to help students achieve high academic standards and enhance the quality of teaching as a profession at all levels of schooling.

The Challenges

Implementing PDS demands a high level of collaboration that can result in a great many challenges for all partners. "Professional development schools (PDSs) are organizations that cannot be created by either public schools or universities acting alone. They grow out of and depend upon collaboration for their very existence. Each partner brings a critical element to the relationship...joint work between these two kinds of organizations can produce cooperation, but it requires each to stretch to meet the other different, if not antagonistic, party" (Robinson & Darling-Hammond, 1994). The trials and tribulations of implementing PDS since 1989 has resulted in the identification of the following major challenges for collaboration and suggestions for addressing these challenges. These challenges and suggestions represent the concerns, perspectives, and recommendations of principals, teachers, clinical instructors, and university instructors involved within our PDS.

Cultural Clashes

Seymour Sarason described in 1984 what our participants have identified as a major challenge to implementing PDS. "I had come to see these collaborations as instances of 'two cultures' interacting - that is, two cultures misunderstanding and clashing with each other" (p.19). Robinson and Darling-Hammond (1994), summarize the factors that distinguish the cultures of public schools and universities as the uses of time, differences in norms and work styles, and traditions regarding status. Participants must work very hard to understand and appreciate one another. Plans should be made to discuss differences in norms, values, and beliefs of both organizations. The culture of each university and school will be different and they all can offer unique strengths while also creating limitations for the partnership. Participants should strive toward developing a blended PDS culture based on the best of both worlds. To do so, participants need the opportunity to study, plan, teach, reflect, and socialize with one another.

Patterns of Power Relationships

"Any educational reform that does not explicitly and courageously own up to issues surrounding changing patterns of power relationship is likely to fail. That prediction is based on the feckless consequences of educational reform in the past half-century." (Sarason, 1991). Perhaps the greatest challenge we have faced while implementing PDS is addressing the issues of status, power and control inherent in our educational systems. We have a long history of well established roles, expectations, and perceptions which serve to separate teachers from students and their parents; while also separating practicing teachers "in the trenches" from teacher educators "in the ivory tower". These established roles clearly differentiate the expected behavior and domains of control of each group and our perceptions create inequality of status, mistrust and at times even antagonism. Teacher educators perceive that they have the theoretical knowledge, access to research and the right to determine the future of teacher education. Practicing teachers perceive that they have the wisdom of practice, the experience, and the right to determine the future of education in practice. Neither group has adequately addressed the rights of students, parents, or other community members. The informal status hierarchy places teacher educators in a position superior to teachers and all teachers are assumed superior to their students. All of these educational stakeholders, in subtle and not so subtle ways, challenge the knowledge, the experience, the practices, the status, and the rights of the others.

Genuine partnerships can only be created when we examine and challenge the expectations and the perceptions which support traditional patterns of power in our relationships. Teachers must be encouraged to utilize the enormous latent power they possess to reclaim teaching as a profession and to become active participants and decision makers in all aspects of the educational system. Students must also be empowered to become responsible for their own learning and the improvement of their educational system. And teachers, teacher educators, parents, and community members must become informed, reflective, responsible, contributing members of the learning community.

Facing The Challenges

A critical component of our ability to establish a successful collaboration has been our collective focus on organizational self-analysis and problem solving. This focus has allowed us to face the challenges we have been presented with and to find ways to address such challenges. The strategies which we feel have guided and enhanced our collaborative planning and decision-making process are synthesized into the following recommendations and trouble shooting guidelines for educators in a PDS.

Create Genuine Partnerships Where All Participants Can Learn, Improve, and Grow Together as a Community of Learners.

Collaborative partnerships must be created between all educational stakeholders including: practicing teachers, preservice teachers, teacher educators, administrators, paraprofessionals, children, parents, community members, social service agencies, and any other educational colleagues. This collaboration develops ownership among stakeholders and provides extra resources in terms of people, ideas, experiences, and support needed to meet the challenges educators must face as they help all students learn and strive to enhance the quality of teaching as a profession at all levels of schooling.

Establish New Collaborative Roles and Responsibilities for all Professional Educators

New creative relationships must be established between schools of education and school districts. Roles for teachers, teacher educators, and administrators within schools and colleges of education must be expanded and boundaries between these traditionally separated roles must be blurred. All educators should view themselves as reflective practitioners, curriculum developers, program planners, evaluators, researchers, decision makers, and change agents; responsible for themselves but also for one another and for teaching as a profession.

Enhance Ownership, Participation and Communication

Educators are busy people who never seem to have enough time. In an attempt to limit time commitments and extra demands on participants, it is easy to inadvertently select strategies which limit ownership, participation and communication. No one wants an extra meeting or another committee to join. But collaborative projects live or die by participants' involvement in all aspects of the project. All participants must feel respected and valued and have a sense that this is "their project". Their voices must be heard, their concerns and suggestions taken seriously, and they must be a part of all major decisions. Multiple communication strategies should be established so all participants are constantly informed of project activities, planning sessions, and pending decisions. Major planning and decision making should be conducted by committees which represent all stakeholders. We have found it helpful to establish an advisory board for each PDS to coordinate within school activities and an overarching board to coordinate activities and communication across schools. We have numerous committees and meetings. The PDS coordinator and the clinical instructor from each PDS meet at least every other week. We also have established newsletters and handbooks within each PDS. Additional strategies to enhance ownership, participation, and communication can be found in the 1996-1997 PDS Goals attached to this paper.

Ownership, participation and communication ensure that project goals are beneficial for all, enhance commitment, and help to establish a collaborative problem solving culture. Participants must plan for many opportunities to create a shared sense of responsibility for personal, organizational, and professional growth. These opportunities take additional time and effort but our experiences demonstrate that they are absolutely essential. The following Trouble Shooting Guide was developed by a PDS principal, Teresa Miller, to offer additional suggestions for effectively implementing PDS.

Trouble Shooting Guide for Educators in a PDS

1. Remember that each member of the partnership is very important, needs to be valued by all, and needs to hear about his/her accomplishments.

2. Remember that parents and students are partners in the project too. Give them opportunities to express their concerns, opinions, and suggestions.
3. Advertise often that the PDS is mutually beneficial and help all stakeholders see those benefits.
4. Gather data to show the benefits of PDS, especially those related to students.
5. Anticipate problems and be proactive in avoiding them whenever possible.
6. Remind participants that every solution has a problem. There will be difficulties, but they need not derail the project. Approach difficulties as problems to be solved and encourage group participation in finding those solutions. Remind participants that we will always be "becoming", that this is an evolving process.
7. Keep communication lines open so that participants feel able to confide in you when they need help in understanding the project.
8. Pay attention to your building culture. Maintain a building goal of being growth oriented.
9. Public school and university cultures are not alike. Work very hard to understand the culture of both entities and translate the differences to your staff members.
10. People who work together need to like each other. To like each other, they need to have plenty of opportunities to get to know each other. Find creative ways to get collaborative time for planning, teaching, and socializing.

We recommend that other institutions involved in a reform agenda consider these challenges and how to address them while considering their own unique sets of strengths, weaknesses, and environmental and social circumstances. Through the development of PDS and attention to these challenges, the Kansas State University's teacher preparation program has been enhanced, the teaching skills of participating teachers and faculty have been improved, and new collaborative relationships have been established between the College of Arts and Sciences, the College of Education, the Manhattan-Ogden Public Schools, and the local Manhattan community.

"For teachers as well as for students trying something new often means initially experiencing discomfort. It may mean getting worse before getting better. The perseverance needed to get beyond adequate performance to efficient, graceful form can be staggering. Teachers need to feel comfortable with their discomfort, knowing that they are supported in their growth" (Loucks-Horsley, 1987, p 9-10). We can not say that we have reached the efficient or graceful form of teaching through Professional Development Schools, but we have learned to become comfortable with our discomfort and to appreciate our own growth, the growth of novice and expert teachers practicing at KSU and within the PDS, and the growth of our collaborative teacher preparation program.

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KSU-PDS Partnership Goals
1996-1997

Enhance Ownership, Participation and Communication

District Level:

- Identify clinical instructor for each PDS to disseminate PDS news and events throughout the school, district, and community
- Develop PDS brochure to distribute to parents, KSU students, and other stake-holders
- Add PDS information to district recruitment brochure
- Add PDS meeting date to district wide calendars such as *Monday Morning*
- Develop items for Board Meetings each year
- Develop partnership video

School Level:

- Establish PDS Advisory Councils to meet once or twice a year. Schools may elect to use existing Site Council for this purpose. Expand involvement to include representatives from: Elementary Education, Secondary Education, Educational Administration, Special Education, KSU students, parents, PDS students, building level Staff Development Council and Site Council.
- Align PDS agenda with building level staff development plans and QPA School Improvement Plans
- Add a description of PDS to Parent Handbooks
- Develop School brochures for each PDS and add a section on PDS to each brochure
- Develop Student Handbooks for all field experience students assigned to a PDS
- Develop a PDS partnership newsletter for each school to document PDS news and events
- Periodically mention PDS events in parent newsletter
- Encourage student teachers and cooperating teachers to write a joint letter of introduction to parents. Develop yearly presentation on PDS for PTA meetings
- Encourage teacher presentations to parents during open house and back to school night explaining KSU partnership and KSU student involvement in the classroom
- Develop a photo display to introduce KSU students and faculty partners associated with each PDS
- Merge the KSU and PDS calendars whenever possible
- Invite KSU PDS team members to PDS faculty meetings, staff development activities, site council meetings, QPA meetings, etc. It should not be assumed that faculty would become regular contributing members of these teams, but that they should be informed of activities occurring in the life of each school and have an opportunity to participate in additional ways within a PDS.

KSU:

- Continue the *Partnership Newsletter* to be sent to all schools and COE departments
- Establish PDS as a regular agenda item for monthly Elementary and Secondary Education meetings and yearly College of Education meetings
- Establish regular meetings with clinical instructors. Disseminate agenda items to KSU faculty and PDS staff so all faculty can be informed of topics of discussion and have the opportunity to contribute and /or participate in decisions involving the PDS.
- Invite principals, faculty liaisons, central administration, and KSU administration to a meeting with clinical instructors once a semester
- Develop KSU speakers bureau or resource pool for PDS

Clarify Expectations for Partnership

- Develop mutually beneficial goals for the partnership
- Develop written description of roles, responsibilities and expectations for KSU faculty and PDS faculty involved in the partnership (clinical instructors, coordinator of PDS, faculty liaisons, mentor teachers, administration)
- Align KSU methods and field experiences with PDS school curriculum
- Disseminate expectations for methods courses and field experiences to PDS faculty (Place syllabi from methods courses and field experiences and textbooks, if possible, in each PDS library)
- Develop written description of field placement procedures

Document Program Effectiveness

- Evaluate all field experiences (from perspective of KSU students, KSU faculty, PDS faculty, and PDS students and their parents when appropriate)
- Evaluate partnership program to examine its effect on KSU students, KSU faculty, KSU program, PDS faculty, PDS programs, and PDS students and their parents (test scores, QPA data, surveys, interviews, focus groups, observations etc.)
- Conduct action research projects

Teaching Teachers to Teach Technology Through TIES

Walter S. Smith, The University of Akron

Teachers of African American and Native American third through sixth graders are learning through the three year, NSF-funded TIES (Technology and Invention in Elementary Schools) Project to improve their teaching of technology (in the sense of applied science, as opposed to computers, etc.) along with invention and problem solving. TIES involves a cooperative venture between (1) schools serving a large minority population (Akron, Barberton, and Canton, Ohio, plus Bureau of Indian Affairs schools in New Mexico), (2) the University of Akron, (3) an informal science center (Inventure Place: Home of the National Inventors Hall of Fame), (4) four Fortune 500 companies (BF Goodrich, GenCorp, Monsanto, and A. Shulman), (5) an environmental education center in a national recreation area (Cuyahoga Valley National Recreation Area), (6) a federal research laboratory (Sandia National Laboratories), and (7) the inventors of the magnetron, fiber optics, electron microscope, and pacemaker.

Instruction occurs over a four week period each summer at the recently-opened, informal science center, Inventure Place, with follow-up during the subsequent school year on site at each school. TIES was planned and is guided by a team of teachers and science supervisors, university scientists and science educators, and informal science center education personnel.

Teachers attend TIES in teams of four from the same building so that during the following year they may be supportive of each other during implementation and so that they may instruct their fellow teachers in the skills learned in TIES. At Inventure Place teachers receive instruction aimed

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at teaching their students the following Benchmarks and National Standards:

- Technology has always been a part of human life. In fact, regardless of Jane Goodall's studies of chimpanzees, one distinguishing feature of humans is their pervasive use of tools. (Other animals use tools; but humans do so consistently.)
- Via technology a wide variety of processes and products are available to solve human problems.
- There is no perfect process or product; these change over time as problems change and as new solutions are developed.
- Even good designs fail, so steps such as pretesting, building in redundancy, and over-designing can be used to reduce failure.
- Solving one problem frequently leads to other problems (and opportunities).
- From some perspectives, technologies have improved human lives; but from other perspectives, technologies do not always lead to improvement.
- Technologies involve costs and benefits; there are always trade-offs such as safety, efficiency, effectiveness and appearance to consider.
- Development of technologies frequently have intended and unintended consequences.
- Technologies always operate within constraints, some of which are imposed by nature (e.g., friction, gravity, and characteristics of the materials being used) and some of which are imposed by society (e.g., environmental, economic, and safety issues).
- Development of technologies frequently progresses through identifying a problem, proposing a solution, implementing the solution, evaluating the implementation, and communicating results.
- Women and men of all ages, ethnicities, educational levels, and so forth, are involved in science and technology.
- Teamwork is frequently involved in technology.

TIES instruction takes major advantage of the Inventure Place resources, including lasers, electromagnetics, strobes, and so forth. Instruction is divided into ten units, each of which is named for one of the National Inventors Hall of Fame inductees. Following are the names of the units, the numbers of days of instruction for each, the invention of the honoree, the TIES activity, and the unit's application in teaching.

- Gertrude Elion unit (2 days).

  Invention: A Nobel Prize winner, she invented several drugs used in treatment of such diseases as leukemia and in facilitating kidney transplants.

  Activity: Using GEMS' Of Cabbages and Chemistry (Great Explorations in Math and Science, 1991a) for grades 4-8, students will test materials' pH. COMETS Science (Smith, 1984) will be used to make connections to Rosalyn Yalow, who won the Nobel Prize for radioimmunoassey, another testing process.

  Application: Teachers will visit the production facilities of A. Shulman, a Fortune 500 company who make plastic pellets that are manufactured into a multitude of products and especially learn about Shulman's extensive on-site testing activities so that they might use this information in their classrooms.

- Stephanie Kwolek unit (3 days).

  Invention: Polymers such as Kevlar, six times stronger than an equal weight of steel, used in bullet-proof vests.

  Activity: Using GEMS' Bubble Festival (Great Explorations in Math and Science, 1992) for grades K-6, teachers will investigate various bubble making formula to test for strength of their products. A second inventor, Waldo Semon, will be introduced here for his particular appeal to students -- he invented both polyvinyl chloride (the pervasive PVC) and bubble gum!

  Application: Teachers will learn about the learning cycle and then apply the learning cycle at a Saturday morning inventors workshop for students from grades 3-6.

- James Hillier unit (2 days).

  Invention: Electron microscope.

  Activity: Using FOSS's "Ideas and Invention," (Full Option Science System, 1993) a third/fourth grade unit, the teachers will investigate the unknown through rubbings, carbon printing, color writing, and reflection. Then they will use the microscope, a technology that supports scientific investigation, as another tool for studying the unknown.

  Application: After this activity the teachers will converse with James Hillier about the process he went through to develop the electron microscope.

- Henry Ford unit (1 day).

  Invention: Improvements on auto transmission; but best remembered for devising mass production processes that greatly reduced the time needed to make a car.

  Activity: Teachers will do activities from "The World in Motion," provided by the Society of Automotive Engineers, of which Ford was an early officer, and learn to use this resource in conjunction with engineers and technicians from their own communities.

- An Wang unit (2 days).

  Invention: Improvements in computer memory.

  Activity: Using "Electrically Speaking" from COMETS Science, teachers will learn about electromagnets and use Inventure Place's electromagnet workbench to explore their properties.

  Application: Building on the learning cycle instruction from the Stephanie Kwolek unit, the teachers will learn about authentic assessment procedures that can be used to assess inquiry learning.

- Charles Steinmetz unit (2 days).

  Invention: After immigrating from Germany, Steinmetz worked through his severely crippled condition to develop the underlying theories of alternating current, the basis of our power industry.

  Activity: Teachers will continue "Electrically Speaking" activities from COMETS Science with particular attention to motors that apply alternating current.

Application: Teachers will be teamed together to learn about and then make plans for their CILC (Cooperative Invention Learning Corporation).

- Willis Carrier unit (3.5 days).

  Invention: Air conditioner.

  Activity: Using GEMS' Hot Water and Warm Homes (Great Explorations in Math and Science, 1991b) for grades 4-8, teachers will investigate energy flow, especially within the home. Here and elsewhere, Macaulay's The Way Things Work (1988) will serve as a reference.

  Application: Teachers will spend three days at the Cuyahoga Valley Environmental Education Center in water testing and so forth, particularly learning about intended and unintended consequences of technology which can have both benefits and costs for the environment.

- George Washington Carver unit (2.5 days).

  Invention: Developed successful crop rotation processes for poor farmers; but then, out of the necessity of needing to find a market for peanuts, one of the crops in the rotation, developed over 300 uses for the peanut.

  Activity: Using "Product Improvement" from COMETS Science, teachers will develop new uses of some common materials, including Elmer's Glue™.

  Application: In small groups for two days, teachers will shadow the R&D personnel at Monsanto, GenCorp, or Goodrich and, under the direction of these workers, engage in a project that illustrates the development work of those industries.

- Wilson Greatbach unit (1.5 days).

  Invention: Pacemaker.

  Activity: Using "Systems and Analysis," a fourth grade unit from BSCS's *Science for Life and Living: Integrating Science, Technology and Health*, Biological Science Curriculum Study (1992). Dubuque, IA: Kendall/Hunt Publishing. at Inventure Place's workbenches teachers will invent something and assess its effectiveness, thereby learning that "failure" can still have benefits and that problems can have multiple solutions.

Application: After this activity the teachers will converse with Wilson Greatbach about the process he went through to develop the Pacemaker and continues to use to make improvements.

- Percy Julian unit (2.5 days).

  Invention: Prior to artificial cortisone's development, natural cortisone, the only available form, was more valuable than an equal weight of gold. His development of artificial cortisone was honored on a U.S. stamp in the Black Heritage series.

  Activity: Teachers will make models of human joints which in certain afflictions are relieved by cortisone.

  Application: Teachers will develop units that apply the instruction they have been receiving and are designed to teach project content objectives. (Teachers will not be asked to completely reinvent the wheel. Their units will liberally rely on materials -- i.e., GEMS, FOSS, BSCS, COMETS -- used in TIES.)

TIES has been influenced in a major way by the work of Dunn and Larson (1990) regarding design technology; and their vision of a design technology classroom is reflected in the instruction provided for TIES teachers. Dunn and Larson envision a classroom something like a workplace with workers (i.e., students) engaged at workbenches as teams. They are pursuing solutions -- as opposed to answers -- to problems posed by the teacher or the students themselves. The problems are practical rather than theoretical. For example, the students may be challenged to make a wind driven land racer that most rapidly moves across the room driven by a fan and also is portable from school to home and back without being broken. And when the race is over the vehicles must be edible!

Students have tools and materials at their disposal. They have paper and pencil with which to compose their solutions prior to taking tool in hand. They work as teams on their design and manufacturing tasks. They receive immediate feedback about the success of their ideas -- it works or it doesn't -- and they have a basis for going back to the drawing board and modifying what they have produced.

Their work throughout the year progresses from problem to problem rather than from subject to subject. When difficulties arise in their pursuit of a solution, the teacher guides them to new skills that will help them -- and surprise, they are learning something else that is part of the school's curriculum.

TIES participants spend two to three days in the workplace at the Fortune 500 companies learning how the skills they are learning to teach are applied on the job. Further, participants spend three days at the Cuyahoga Valley Environmental Education Center in the Cuyahoga Valley National Recreation Area learning about positive and negative effects of technology on the environment. Recall that about 25 years ago the Cuyahoga River caught on fire in Cleveland and could not be extinguished for several days. This incident accelerated the development of a national recreation area along the Cuyahoga. The river's health has noticeably improved. Technology can have both positive and negative consequences.

Each summer two inventors of, e.g., the electron microscope and the pacemaker, informally interact for a day with the teachers so they learn first hand about how honored inventors problem solve. During the subsequent year TIES instructors, supported in New Mexico by science educators from Sandia National Laboratories, visit each teacher at least four times, doing everything from teaching demonstration lessons, to co-teaching, to observing and providing feedback, depending on the teachers' needs.

TIES has woven together research on (1) encouraging underrepresented students in science, (2) teaching and learning problem solving skills needed in a post-industrial, global economy, and (3) changing the practices of science teachers. For example, based on the work of Kahle (1985), Lockheed (1985), Smith and Erb (1986), and Smith (1991) nine *Cardinal Principles* for encouraging underrepresented students in science are applied, including:

- Teach science through firsthand (hands-on) experience, applying a constructivist approach.
- Reorganize instruction to encourage cooperative learning.

- Actively encourage underrepresented students to engage in science, math, and computer activities in and out of school.
- Use language the students understand during instruction.
- Develop students' positive evaluations of their own competence in science.
- Make science people oriented by emphasizing science topics that focus on personal utility and the altruistic/nurturing value of science.
- Bring aesthetic appreciation into science.
- Capitalize on girls' interest in and mastery of oral and written skills by including language activities and classroom discussions in science.
- Incorporate community resources in instruction.

TIES has been designed to apply seven characteristics of science programs that both teach and apply problem solving in science, including:

- Start with practical problems; then move to causality issues. Children's interest in science experiments is heightened by starting in an engineering mode in which students investigate practical problems and then over time move to a scientific mode that focuses on causal relationships (Schauble, Klopfer, & Raghavan, 1991).
- Problems need to be "practical" from the students' perspective. Children's problem solving skills are enhanced, if they feel ownership of the problem -- i.e., they see the problem as relevant (Pizzini, Shepardson, & Abell, 1989).
- Discrepant events with student questions and teacher guidance support problem solving. Discrepant events, accompanied by (1) student-generated questions and (2) teacher guidance on how to ask productive questions, support development of both problem solving skills and understanding of the topic at hand (Barr, 1994).
- Children should be reflective about their problem solving efforts. Children's problem solving is improved, if they (1) are led by the teacher to reflect on the strategies they used to solve the problem and (2) they have standards by which they can evaluate their performance (Barr, 1994).

- Working in cooperative groups enhances problem solving. Cooperative groups in which students together investigate questions, propose and test hypotheses, and draw conclusions enhance development of both problem solving skills and understanding of the topic at hand (Johnson & Johnson, 1987).
- Hands-on, process-oriented instruction yield higher achievement than textbook-oriented teaching. Regardless of teacher experience and school location, contrary to "back to basics," elementary students enrolled in process-oriented classrooms enjoy higher academic achievement than students in textbook-oriented classrooms (Shymansky, Hedges & Woodworth, 1990; Shymansky, Kyle & Alport, 1983).
- Academically or economically disadvantaged students appear to gain the most from activity-based elementary science programs (Bredderman, 1982).

Finally, TIES takes into account research on the change process in education. In this regard we were very influenced by Taking Charge of Change by Hord, *et al.* (1987) and their Concerns-Based Adoption Model. Further, Mohling (1993) found that professional development in science for elementary teachers of American Indians required both a period of instruction and an extended period of application before the teachers' primary concern moved from self concerns to concerns about the effectiveness of the innovation.

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MENTORING THE BEGINNING SCIENCE TEACHER: FACILITATING THE DEVELOPMENT OF A REFLECTIVE PRACTITIONER

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Induction Programs and The Needs of the Beginning Teacher

New teachers enter the classroom with idealistic expectations about students, classrooms and teaching, but the transition from student to first-year teacher promptly shocks them into reality (Gold, 1992). Research has shown that the first few years of teaching can influence the quality and professional growth of the novice teacher for the rest of their teaching career (Huling-Austin, 1990; Odell, 1989). "Without a bridge between theory and full professional practice and responsibility, learning on the job remains hit and miss, inefficient and painful, and the experience of entering the teaching profession continues to be largely a matter of sink or swim" (Johnson, Ratsoy, Holdaway, & Friesen, 1993, p. 298). It is clear that novice teachers need careful and systematic assistance during the beginning of their careers (Berliner, 1985; Johnston & Ryan, 1983; Veenman, 1984; Thies-Sprinthall, 1990).

Researchers have documented the perils of novice teachers who are not adequately supported during the first year of teaching. Providing support and assistance to new teachers is needed to change the tradition of "isolation, survival, and trial-and-error learning" (Feiman-Nemser, 1983; Wildman, Niles, Magliaro, & McLaughlin, 1989). Currently over 31 states have implemented mentoring and/or induction programs. The aims of these programs are to "retain and induct novice teachers, reward and revitalize experienced teachers, and to increase professional efficacy" (Huling-Austin, 1989, p. 5). These induction programs have contributed to the educational system in the following ways: improved retention of teachers, increased positive attitudes toward teaching, and improved performance of teachers (Smithey & Evertson, 1995; Feiman-Nemser & Parker, 1992; Huling-Austin, 1990; Klug & Salzman, 1991; Yosha, 1991).

Effective mentoring programs are designed around what learning-to-teach research has revealed about novice teachers' needs. Well-designed "mentoring interventions" assess the level of teacher development of the novice teacher and then facilitate the development of teacher expertise through construction of a teaching knowledge framework. This framework can be used by the protege to reframe their "novice" experiences from a more "expert" perspective (Odell, 1989). While this information provides the needed base for continued development of induction programs, further research is needed to provide field-based data regarding individual mentors' contributions to interns' learning to teach. Such information is essential if we are to understand how a supportive mentoring environment may contribute and even transform the process of learning to teach.

Guiding Question

Specifically in the context of science education, the findings generated from this study contribute to a more in-depth understanding of the trials and tribulations of beginning science teachers. Further, this study also contributes to an understanding of how a mentor can help his or her protege make the transition from "science student" to "science teacher." Therefore, the guiding question of this study was, "How does an experienced science teacher (mentor) help a beginning teacher (protege) learn to teach?"

Methodology

To answer this question, a mentor/intern pair was observed four days a week for one semester. On a typical day the researcher would arrive at 6:45 a.m. and leave when the mentor or intern left at the end of the school day.

Internship/Induction Program

The intern was enrolled in an internship/induction program at a southern university. This program allows college graduates to earn a master's degree plus certification to teach in 14 months. Interns are required to teach for a semester at two placements, i.e., one semester at a high school placement and one semester at a middle school placement. They share a classroom with an experienced mentor teacher who guides and facilitates the learning-to-teach process. The mentors participate in a week long inquiry-based workshop during the summer prior to having the interns share their classrooms. They also attend follow-up meetings twice during the semester.

Participants

The intern, Mike (pseudo-name), had graduated from an ivy-league school with a bachelor of science degree in biochemistry and took two education courses while he was there. After graduating, Mike spent one year in Europe teaching at a boarding school. He taught three classes including physics, algebra, and biology. After returning to the United States, he worked for two years as a program director for a summer camp before applying to the internship program.

The mentor, Carol (pseudo-name), had taught science for 27 years. Her experience included elementary, middle, and high school level teaching. She was the recipient of many honors and awards, including the Presidential Award for Excellence in Science Teaching, the Tandy National Scholars Award, and the Presidential Distinguished Scholar Award. She was highly recommended by the director of science and health for the public school system of this southern city. He referred to her as the best science teacher in the county. During this research study she taught Honors Biology, Advanced Placement Biology, and Anatomy and Physiology. Carol also had extensive experience with teaching adults through conducting inservice workshops and through serving as a cooperating teacher for student teachers.

Data Collection and Analysis

The data analyzed in this study included field notes from observations, transcripts from video and audio tapes of interviews and observations, a dialog journal kept by the intern and mentor, a reflective journal kept by the intern, lesson plans and other intern-generated class materials, and email messages written by the intern to the researchers. Methods of qualitative data analysis (Borg & Gall, 1989; Lincoln & Guba, 1985; Miles & Huberman, 1994) were used from the beginning of data collection in order to facilitate the emergent design, grounding of theory, and the direction of later data collection phases. The researchers used the Constant Comparative Method developed by Glaser and Strauss (1967) to focus on the specifics that made the context unique and to generate the information upon which the emergent design and grounded theory could be based.

Findings

Six mentor functions emerged from the data analysis that appear to have been essential for this mentor to effectively facilitate the growth of a beginning science teacher: gate-keeper, model/guide, reflective practitioner, co-planner, co-teacher, and co-learner. Each function was used by the mentor in a unique way to help the intern navigate the dilemmas and decision points that comprise the complexity of teaching.

Gate-keeper

The beginning teacher, in essence, is entering a foreign land and the mentor serves as a gate-keeper to that land. As a gate-keeper, the mentor performs functions such as giving the intern a tour of the building and introducing him to key people or describing the history, culture, and politics of the school.

In her role as gate-keeper, Carol was open, honest, and inviting. She first opened the door for her intern to her students and her classroom. Mike described this when he said,

> *"She (Carol) immediately included me in her thoughts. From the simplest thing such as writing my name along with hers on the syllabus to asking me what I was interested in helping her with. The whole process was completely open. She gave me permission to ask questions directly and she was honest in sharing her own nervousness in having someone else in the classroom with her, which makes the whole year seem much more a team effort where both of us will learn. She set her expectations clearly, but without ever making me feel that I was on the outside of them. We talked about how she deals with students, past history of the school, the school culture, and the atmosphere she tries to establish in her classes. This was extremely helpful in providing me with some idea of what to expect on the first day of school."*

Carol also opened the door to the school and its traditions and she helped pave the way for Mike's acceptance by the faculty.

> *"I met with Carol at 9:00 A.M. and she showed me the building and her classroom. We then sat and talked about the history of the school, the make up of the students and traditions of the school. Before I even realized it, two hours had past. The atmosphere was light, excited about the coming year, and open for sharing ideas and personalities."*

The first faculty meeting of the year occurred the next day where Carol introduced Mike to the faculty and made sure that he met the key people of the school, i.e., the principals, the secretaries, and the janitors. As the semester progressed she continued to open doors for Mike by suggesting

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his name for special projects and encouraging him to serve on committees and participate in other activities that would look good on his resume.

Another door that was opened was one of friendship. Mike described this when he said,

> *"From inviting me to dinner and a concert to simply talking on the phone regularly, she has quickly become a friend. She is the type of person who invites people into her life. She is a swirl of energy that is a whirlwind and a calm lake all in one."*

Typical of many first year teachers, Mike was alone and in a new city, away from family and friends. As a mentor, Carol took the time to show compassion and caring for this young teacher and began to build trust and friendship with her protege.

Mentors can open gates to the school, students, parents, and other faculty members for their proteges. Without the benefit of a gate-keeper new teachers may have to endure some painful experiences before they learn the idiosyncrasies of the school's culture. By introducing the protege to key people and informing the new teacher of the culture and politics of the school, the mentor can help prevent mishaps and misunderstandings and help smooth the beginning teacher's entry into this foreign land. The function of gate-keeper is especially important during the beginning stages of the mentor/intern relationship. Equally important is the role of model/guide. By watching master teachers in action, novice teachers gain insights into the craft of teaching and are able to tap into the wisdom and experience of those teachers as they demonstrate and unpack the complexity of teaching.

Model/Guide

As a model/guide, the experienced science teacher demonstrates the full spectrum of thinking, decision making, and actions that occur in a science teacher's professional life. This spectrum ranges from the intricacies of planning ahead for science labs so that supplies will be available when needed, to developing a classroom climate that is conducive to critical thinking and risk-taking.

Planning for the beginning of the school year can be overwhelming for the beginning teacher. Mike expressed how beneficial it was to see how Carol prepared for the beginning of school. The following dialogue was from one of their first meetings before school started.

Carol: *First of all we need to set up a filing system. Each class will have a different color so that at a glance you can tell if everything is filed right. We will have one set of folders for the students' use and one set for our use. We color them by the rainbow so the first period will be red, second period orange, yellow, green, and blue. Independent study and student assistants will be purple. Our set of folders will be used to document behavior problems or even study problems. The students' set of folders will be for absentee work. When they are absent we will put any dittos or activities that they missed in their folder. It will be their responsibility to look in their folder as soon as they get back to check for work they have missed. I also suggest to my students to find a buddy in each class. This needs to be a person that pays attention, not necessarily your best friend. Make sure and get his or her telephone number so that you have someone to contact if you are absent. It is the students' responsibility to make up their work within three days after they return, never more than a week. Another way we will help the students keep up is by putting out calendars each month with assignments, long term projects, and tentative test dates. Because this is an academic magnet, students can very quickly become overwhelmed by the number of assignments, so I try to encourage them from the beginning to be proactive and plan ahead to keep from getting behind.*

Carol went on to discuss decisions that must be made such as when to hand back tests when students are absent, how to encourage students to use their time wisely, and how to help ninth graders acclimate to high school. They also discussed such issues as lab fees, ordering lab supplies, and how to pass out textbooks.

The administration at Carol's high school had made the decision to try block scheduling which involved classes meeting every other day. Carol helped Mike think through the various implications of this type of scheduling.

Carol: *Planning for an hour and forty-five minute class is a whole different ball game than planning for a 45 minute class. You have to vary the activities to keep their attention. Also because in a normal week we will be seeing them every other day, we may want to have them take tests before school, during lunch, during independent study, or after school so that it doesn't take up so much class time. In weeks that we have field trips and special programs there could be large gaps of time between when we see certain classes and therefore it becomes very important that they have a clear understanding of what we expect from them.*

Throughout the semester, Mike expressed how much he was learning by watching Carol teach. Carol tends to use the Socratic method to lead discussions. She has developed an incredible style of asking questions that help the students move beyond superficial learning. In one journal entry Mike wrote:

> *While I was teaching in Europe I felt a duty to cover the content almost to the point of losing sight of the broader goals of self-esteen, personal reflection, and deeper understandings of an interconnectedness with the world that we live in. Carol has successfully combined these elements, much is because of her ability to concept map in her head. From her years of experience, she has built frameworks of content and life-changing*

> *questions which she can access at will. Already this has influenced me to ask deeper questions about the content I am studying to teach.*

Another area that Mike described as invaluable was seeing Carol plan for, carry out, and evaluate laboratory experiences. She attempted to unpack and describe every detail of planning for a lab, i.e. ordering supplies, setting up the lab, designing questions that prime the students' thinking without giving them the answers, facilitating and managing students' learning during the lab and evaluating students learning during and after the lab.

At the beginning of the semester Carol spent a lot of time modeling for Mike. This seemed important to help Mike get an idea of how things worked. Once he started teaching, Carol became more of a guide and resource especially in helping Mike reflect on his teaching.

Reflective Practitioner

Modeling is not enough; the mentor must provide opportunities for the intern to discuss the whys and hows of what has become second nature to the experienced teacher. Reflective discourse about students, effective teaching strategies which support students' construction of knowledge, and classroom management are invaluable to beginning science teachers.

During their planning session, Carol asked Mike to call role before each class on the first day of school. Mike had asked the students to tell something interesting about themselves when he called out their name. Because of the class size this was taking much too long. Between classes Mike asked Carol what he should do. Together they quickly brain stormed some alternative methods and he chose to have the students give an adjective that best described themselves. Mike described this in his journal:

> *"Today in class I realized something was not working the way I wanted. I talked to Carol about changing it, and then proceeded to correct it for the next period. Having the chance to meld thoughts on the spot with someone so dynamic has opened my eyes to new ways of teaching."*

On other occasions Mike would ask Carol about the "whys" behind her teaching and decision making. After reflecting with Carol, Mike wrote this in his journal:

> *While I need organization for myself as I am new to teaching, Carol has intuitively done this. Some of our working together will involve my getting her to verbalize these intuitions so that I can gain not only the information but also the process of internalizing the organization.*

Once Mike began teaching Carol would sit down with him during planning period or sometimes immediately after he taught a class and they would reflect on what went right, what went wrong, and other questions designed to help the intern unpack his lesson. On one occasion Mike had tried to teach the nitrogen cycle to his honors biology class. Because of his biochemistry background, the nitrogen cycle was very easy for Mike to understand, however, when he tried to teach it he realized how difficult it was for the students. The following dialogue is from the feedback session following this lesson.

Mike: *It seemed to me it turned much more into the teacher saying see here you should have known this beforehand. To begin with it wasn't good teaching. It wasn't well done. My plan was to focus on the bigger ideas but I got derailed, I got lost in all the little details.*

Carol: *I get lost in the nephron. I understand.*

Mike: *Part of that has to be with my being a first year teacher but I do think there are elements of it's far too much detail to keep up with here and if I get lost how can I expect the students to understand it? And then I was going to use the carbon cycle where we developed that overhead by thinking about how it relates to us and then go into phosphates but I felt like I was running out of time and so I asked them if this type of teaching was working for them and they said no. So I wanted to pick back up with the nitrogen cycle and make it less complex but because I hadn't planned for this it made it worse. I couldn't think how to make it more simple.*

Carol: *Let's try to think how we could simplify this. You mentioned before that you like to try visualization techniques. Do you think there is a visualization technique we could do with the nitrogen cycle that they could relate to more? How could we model what they need to do to understand it?*

Mike: *Well see that is interesting because when I think of the nitrogen cycle I have chemicals in my mind because once you know the chemicals and get them moving around in a cycle, there isn't much more to know. What I was trying to do was to give them particular terms that they need to know such as ammonification, nitrification, denitrification, and nitrogen fixation.*

Carol: *Okay, going back to the original thing of how you think they can do it, especially chemistry. This is the first thing they hit that is like that. What kind of activity can we do that would model their actually walking through the cycle?*

Mike: *We could have one group that is a plant, one group that is an animal, one group that is whatever, and the individuals are the bacteria.*

Carol: *And then we could thread the nitrogen hooked to someone else...and have signs saying plant or whatever, because we talked to them about picturing biomes but they may have a hard time visualizing molecules.*

Mike: *Oh they were so lost and I wasn't defining things properly. Part of that was I was thrown off because I was going to originally use the overhead for the carbon dioxide and have them use that as a clue to trigger ideas and develop it and I couldn't find it. I still don't know where it is.*

Carol: *That happens to me too. In fact it is a good idea to have a plan B or think about several ways you can present it in case plan A doesn't work.*

Mike: *No it is not in the text and there are too many lines on it. I mean there are too many things that are going on.*

Carol: *Perhaps we could get some yarn or string and make some signs and have the nitrogen molecule go through and have the oxygen come in where it needs to come in and then have them move into the membrane but not worrying about the pluses and minuses. I have not done it that way but that is one way to do it. Usually I will get a simplified diagram and actually walk them through step by step, really, really slowly. The students were saying they were confused and they needed help. Sometimes I will ask them what they have done to understand to make sure they have done their part to understand. Then I try to pinpoint where exactly they are having the problem. Another technique I have used is for them to get a partner and try to work through it together, sort of teach it to each other. You may decide to use a simplified diagram. You may do some modeling or you may just want to walk them through without any extraneous stuff. Just walk them through the steps. There are a lot of different ways to do it. You might even name the molecules. I use to talk about Fred the water molecule. Anything to help them focus. One of your strengths is that because of your background, you understand it so well. But sometimes when something seems easy for us, it is difficult to think back and understand why some people don't understand it well.*

Carol continued to try to help Mike come up with a way to reteach the lesson. At first he was very resistant to reteaching it. He even said that he didn't think that the biogeochemical cycles were important enough that they warranted further frustrating the students. Carol patiently explained how the cycles are building blocks for further learning. This eventually resulted in breakthrough learning for Mike when he began realizing the vast gap between his level of knowledge and the students level of understanding.

Reflection is a crucial part of learning to teach. Mike needed to be able to ask questions such as why did you respond to Susan in that way? How did you decide to go on a tangent with David's idea but not with Nancy's? It was also important for Carol to unpack her thought processes and discuss important factors of teaching that Mike may have missed completely.

Carol not only modeled reflective practice, but also served as a mirror to help Mike think about his own teaching. Carol served as a "guide at the side." Mike pointed out that it was very helpful to have another pair of eyes to view the classroom through. Carol provided a lens through which Mike could gain another perspective of a complex and dynamic process.

Mike also mentioned how helpful it was to reflect on the developmental levels of the students and to learn how to use this knowledge in planning for instruction. Mike and Carol incorporated the knowledge gained from this reflection time into their planning.

Co-Planner

As a co-planner, the mentor acts as a tremendous resource by making available to the intern years of accumulated materials and insight into how to effectively use these materials. The mentor has effective "hooks" that catch students attention and get them excited about science. These ideas and materials can serve as springboards to beginning teachers who can use them as is, modify them, or create new materials inspired by the mentor's resources.

From the beginning of the semester Carol wanted Mike to be a partner in the planning. Carol had decided to begin the classes with a demonstration that she had seen at a workshop led by Stephen Covey. She encouraged Mike to add any ideas and he came up with an activity from camp that connected perfectly.

Planning can be a daunting task for a beginning teacher. There are so many aspects to think about, i.e. learning styles, developmental levels, time factors, scope and sequence, state frameworks, National Science Standards. Carol consciously attempted to give rationales and explicit details of her thought processes during her planning.

Carol: *I to have the ecology unit pretty well mapped out by Friday. I will do the same for chemistry, biochemistry, cellular function, membrane function and we will continue to do it unit by unit. This will give you a framework of what I basically try to explore with the students. I would appreciate any comments or suggestions from you. You have just graduated from college and I am sure you are aware of the latest research, especially in your area of expertise.*

Mike: *There is so much information. We surely can't cover it all. How do you select what is important? Can you give me an idea of what your class looks like? How deep do you go? How do you organize it into a cohesive whole?*

Carol: *What I have found that works for me is to take big ideas such as interdependence, homeostasis, form fits function, chemical structures in terms of biological function, life takes place in solution, proteins are us... anything I teach fits under those ideas and that's how the natural world works. What is the saying? Don't give them a fish. Teach them to fish. Therefore, they need to learn the natural laws that are in the world and they are dependent on that. To me if everyone would teach them this now then the next generation would stand up and say don't mess with clean air. Don't mess with clean water. Let's all work together for solutions. This is all one planet. It is an enclosed system. You have to start with things that they can relate to immediately. That is why I start with ecology. It is something they understand. They can relate to it. It ties together everything else. Every unit I teach I keep coming back to the big ideas. It explains everything. I'm teaching the same thing every unit with different content. This also helps them to be very predictive because once they start catching on to the big ideas the students can predict how the next unit will relate to these ideas. Other components of my teaching are: I can learn from every student; I am interested in what they think; I expect questions; I expect questions I cannot answer (those are the most important* *ones). Hopefully they come out of my class believing they can do it. They can do science.*

Mike: *That gives me the big picture. How do you plan for the details?*

Carol: *I take the state framework, the science standards, textbooks, course outlines and then I see how it all fits with the big themes. Then I start planning when I need to schedule certain units. I have to consider how different units build on each other. I have to consider the seasons, i.e. the plant unit is good to do in spring or fall. Other things I try to keep in mind are time factors. How much time do I need to cover a unit? What about holidays and breaks and what does that do to the student's frame of mind? In Advanced Placement Biology we have to consider when the test date is and what areas must be covered by then to prepare the students. Next I break it down by weeks and then by lessons. I don't necessarily do the same thing each year. I am constantly looking for new ways of presenting things or new activities to try. There is so much to choose from and the best thing to do is to try things and keep a notebook of what works or doesn't work and why it does or doesn't work. I want to help you make a notebook for each unit and I will give materials to you that I have used in the past. This will give you something to start with when you are planning for your classes next year.*

Once Mike took over teaching completely, he expressed how wonderful it was to have Carol to go to for ideas. He described her as "*a tremendous resource. It is kind of like having free access to a candy store. There is so much to choose from.*"

In the beginning Carol and Mike always planned together. Mike would describe what he wanted to do and Carol would help him think it through. She would provide scenarios of how the students might react and then let him try to think of how he would respond. She sometimes would say, *"I don't think this will work."* She would proceed to explain her reasoning behind this statement, but if he still wanted to attempt his idea she would give him room to try. Sometimes this resulted in success and other times failure but in either case they both were humble enough to learn from the experience.

During one planning session near the beginning of the semester Mike wanted to place students in groups for an activity. Mike explained what he wanted to do and Carol very briefly suggested that he take the time to make his expectations of group work clear to the students. Mike chose not to take the time to do this and the following dialogue came from the next feedback and planning session.

Mike: *I started off the class with a short discussion and that worked out great but when I divided them up in groups it disintegrated.*

Carol: *What did you want to happen in the groups?*

Mike: *I wanted them to work together and all participate. I wanted them to realize that they have a lot to offer and that they don't have to be silly to get attention.*

Carol: *Do you think it is time to talk about group process? What do you expect from group work? Make this clear to them. Talk about everyone's rights and responsibilities. I have a right and a responsibility to contribute. I do not have a right to ruin the group's focus or disrupt the group. There are basic rules for cooperative learning and we need to discuss this with them.*

Mike: *I thought the assignment was clear and they would just know what to do.*

Carol: *Tomorrow why don't you pull them back together and have them think how groups should work together.*

Mike: *I really don't want to spend too much time on it. I think I will just say, "Yesterday there were some interesting interactions between the four different groups. You may want to think about it as a group how you want to work and what your goal is." But I don't know that I would go further than that. And I guess my question is do I need to go further than that? Because I generally at all cost avoid any confrontation with students.*

Carol: *Part of thinking through this is putting yourself in their place. The students come from all over the city . They come from vastly different backgrounds. Some of them have very strict traditional training and some of them have been exposed to more open-ended type of curriculum. Some of them have gotten by with doing very little because they were the brightest in their class. As ninth graders they are worried about grades but they are also concerned about connecting socially. Also because they come from such diverse backgrounds they have various perceptions of what group work is and if there hasn't been clear expectations either developed with the students or just given from the teacher or taken from a cooperative learning book, then they are coming with whatever their idea of group work is. So when you say you don't want to spend a lot of time on it . . . there is not some clear cut frame of reference that we are dealing with when we go to groups then we are talking about maybe 24 different frames of reference for group work.*

Mike struggled with the ideas of control and confrontation. He was totally against teacher centered classrooms, but his understanding of the alternative was not clear. It took many reflective conversations between Carol and Mike to help him come to an understanding of what *"teacher as facilitator"* means. Later in the semester he made this statement,

> *"I am learning that students need guidance and they need a framework to operate within. That is not teacher-centered. It is being a facilitator of the students learning. Students have incredible thoughts and ideas to share but as a facilitator I must come up with the activities and questions to prime their pumps and the parameters for them to operate within."*

Mike described his planning sessions with Carol in this way,

> *"It has been truly phenomenal to work with Carol on planning lessons. She does much of this intuitively storing in her mind the discussions we have and recreating them during class. She is great at leading open discussions and she has themes ingrained in her mind, in part from her vast teaching experience, but also from having read so widely that she can access vast quantities of relevant stories and thoughts seemingly effortlessly. She writes little down. I would like to get to that point."*

At the beginning of the semester Carol was careful to include Mike in every aspect of teaching, however, at first it was clearly much more Carol's input. As the semester progressed Mike began to contribute more and more until he was doing the major part of the planning. They soon became a cohesive team and they could pass the teaching wand back and forth during a lesson without missing a beat. As co-teachers and co-learners they developed a synergistic relationship.

Co-Teacher

Finally, when the mentor and intern teach together, the mentor acts as a co-teacher. The mentor and intern plan and teach as peers and then reflect on the lesson as co-learners. Each person can contribute from their own strengths and the students get the best of both worlds. The synergy that develops from this partnering creates a fertile ground for construction of teaching knowledge by the intern. The mentor plays an important part in facilitating this growth.

Getting to the point where both mentor and protege can work as peers requires successfully clearing many hurdles. The mentor must learn to trust the protege enough to let go of his or her class. Carol expressed this in the beginning when she said that she was nervous about letting go of her time with the students. Carol had a deep love for the students and she felt a strong responsibility for their growth in her class. She wanted them to have the best opportunities to learn. Mike also picked up on this and describes it in his journal:

> *"Carol has tremendous energy and knowledge. I need to consider what to bring to the relationship for my strength is in my creativity and interaction with the students. How is it possible to give back all the knowledge and energy she is providing me? Once I know Carol better I will feel more relaxed at helping her teach the class. I am fully confident with the content but I can see that she is after much more than that for her students."*

About a week later Mike continues on this same subject,

> *"I had an incredible conversation with Carol today. It was amazing the amount of trust that developed between us during this conversation. For the first time I internalized the fact that she loves these kids to the point of being fearful of someone else coming in and taking them from her. As any great teacher she is protective of her time for she has proven that she is effective. Any time from her is almost a gap of possibility. Having her begin to let go of her students will not be easy."*

Throughout the semester there were visible signs of progress on Mike's journey to becoming a teacher. On one occasion Mike described one of these mile markers.

> *"I had asked a rather far-reaching question and I realized it was not in the flow of where these students were. Having this type of realization and gaining the ability to step aside and leave the issue for another day was an exciting step for me. Even more, being able to pick up immediately with some other aspect of the subject without referring to my lesson plan means I am slowly acquiring a teacher's sense of where ideas are going."*

Later Mike described further growth when he said,

> *"I feel that I am slowly gaining an ability to go off on tangents that the students bring up while still keeping in mind some of the analogies and links that I want to make with the material and what the students are considering."*

Not too far into the semester Mike and Carol began to truly team teach where either could take the lead on a moments notice . . .

> *"I was grading papers when Carol suddenly had to leave the room so I stepped in and picked right up with the students next comments. That was an exciting moment to completely trust the process and let the students lead me where they were going in the discussion. I can think on my feet!"*

Mike is describing his transition from thinking like a student to thinking like a teacher.

At the beginning of the semester Mike was almost overwhelmed by the magnitude of Carol's personality and ability in teaching. He tried to imitate everything she did. Another sign of growth and confidence as a teacher was when he realized that he didn't have to be Carol's clone to be a good teacher.

> *"Carol works well without very established plans, but rather a vision of where she is headed and how she works with kids. I realize I have been subordinating my own personal vision to that of Carol's as she represents the mentor with experience. But that is not quite the way to proceed. Instead, Carol offers insight into how varying styles can still produce wonderful results. She simply can do things that I am not comfortable with, interacting with the kids through means that do not come naturally to me. She is more comfortable and loose around them. She offers her life as a somewhat open book. These elements work for her because they work in her personality. It is easy to see that she is confident. This builds the students' trust. I however need a bit of distance. It has been good to slowly come to the conclusion that I do not need to be like her. She has a tremendous amount to offer, but I am not her nor can I be her."*

Carol had expressed concern that Mike was trying to mimic everything she did. She tried to help Mike follow his own instincts and develop his own style of teaching. She continually reminded Mike that there were many ways to do things and she tried to encourage him to follow his own ideas and take risks. As his confidence grew, he began to follow his instincts and to see how his teaching style was different than Carol's but just as effective.

Mike's confidence grew, as did Carol's belief in Mike until it reached the point that she could turn her classes over without reservation. Carol expressed this when she said, *"I just realized that I have completely turned over all the classes to Mike and I feel comfortable with doing that."*

Co-Learner

Mike and Carol became co-teachers but they were also co-learners. In the beginning Mike was mainly the learner but as the mentor/protege relationship became established and trust was built, Mike began sharing ideas and bringing in articles and materials. Carol talked about this during a conversation I had with her.

> *"At the beginning of the semester it was almost overwhelming the demands of putting 100% into my classes and then pouring all that energy into encouraging and guiding Mike. At times I wasn't sure if it was worth it or if it was making a difference but quickly that changed and Mike began to blossom. I began learning so much from Mike. He brings great ideas from his methods class at the university. Some of which I am sure I will use next year. It is difficult to stay abreast of the latest in science. I am an avid reader of* Scientific American *and other science journals but it has been great to have Mike contributing new articles and his knowledge from College. I know my students have benefited too from having someone with different strengths. I think we made a great team. Our teaching styles complemented each other and in a way our sum was greater than our parts. Another growth area for me was having to rethink my teaching. I am basically a very reflective person but I have had to ask why about a lot of things that I have done automatically for years. It has been great to have another adult in the classroom to share and bounce ideas off. I have been asked to write a textbook for Anatomy and Physiology incorporating some of the new ideas of mind and body wellness and it has been helpful to have Mike to provide insight into some of the activities I have tried this year. All in all I believe I have learned as much as he has."*

Mike described being a learner when he said,

> *"It has been good to watch Carol teach. Her ability is tremendous for she reads people incredibly well. Further, she transforms the academic questions into personal inquiries. I have learned so much from her. I could never explain everything I have learned. Carol was a friend, an advocate, a challenger. She pushed me but also provided a cushion when I fell. Her guidance and encouragement were invaluable. Even though I taught a year before I came into this program, I have learned so much more this year. It seems that sharing a classroom with such an experienced teacher and being able to hear her think, bounce ideas off of her, and draw from her wealth of knowledge and resources has multiplied my learning opportunities and therefore my learning."*

Summary

Gate keeper, model/guide, reflective practitioner, co-planner, co-teacher, and co-learner emerged as important functions through which Carol mentored Mike. In this study the mentor seemed to provide the assistance that served as a bridge to the intern. Instead of allowing the intern to sink or swim, she carefully and systematically facilitated his movement toward professional efficacy. From the beginning of the relationship Carol carefully assessed the level of Mike's development as a teacher and then delicately balanced the amount of "supporting" and "challenge" to ease his development of teacher expertise.

Unlike many first year teachers who have little time to process and reflect on their teaching, Mike was able to share the responsibilities of a classroom with a seasoned veteran. This not only provided more time for contemplation, but also another more experienced point of view. Mike not only had his "novice" frame of reference to process and reflect on his teaching, he also had Carol's "expert" perspective to help reframe his experiences.

Mike summed up the benefit he experienced from having a mentor when he said, "It seems that sharing a classroom with such an experienced teacher and being able to hear her think, bounce ideas off of her, and draw from her wealth of knowledge and resources has multiplied my learning opportunities and therefore my learning." Instead of questioning whether he wanted to stay in teaching, Mike ended the semester looking forward to having his own classroom where he would continue his journey of learning to teach.

Conclusions and Implications

The use of a mentor is one answer to the problem of providing support for beginning teachers. Instead of isolation, survival, and trial and error learning, mentors offer novice teachers companionship, guidance, and opportunities for reflection which may ease the transition from student of teaching to teacher. For this to occur the experienced teacher must be willing to open doors, model teaching expertise, facilitate development, provide opportunities for reflection and collaboratively plan, teach and learn with their mentee. Fulfillment of the role of mentor requires an incredible amount of time and mental energy. There are many dilemmas for a novice entering a world of experts; therefore, it appears the mentor needs to be acutely aware of the intern's needs and act in a manner that promotes personal and professional growth. For a novice teacher who has a need to be accepted, valued, and heard on a personal and professional basis, it appears that mentors' investments of time and mental energy are invaluable.

Case studies of mentor/protege relationships provide a lens into the world of learning to teach. They provide insights into how we can and cannot facilitate this process. These case studies also provide a glimpse into the minds' of novice teachers allowing researchers/practitioners to see from the perspective of a beginning teacher. This information can be used to design more effective ways to increase positive learning experiences for beginning teachers.

More case studies of both negative and positive mentoring experiences need to be available for both prospective mentors and proteges to read. The effect of this might be three-fold: 1) Teachers that are already mentors could learn from other mentor's experiences; 2) Prospective mentors would become aware of the tremendous amount of time and energy required to be a mentor; 3) Beginning teachers would become more aware of their role as proteges and how they can best ease the mentoring process.

Finally, case studies can be used by administrators to learn more about the characteristics needed to be an effective mentor. Much of the past research is from broad studies that looked at a large number of mentors. Case studies paint vivid pictures of mentors who have learned to facilitate the growth of beginning teachers.

I close with a quote from Daloz (1986), which summarizes Mike and Carol's relationship and reiterates the ability of mentors to empower their mentees:

> *For each of us tangled inside our own stories, the endings are hidden. Yet most of us spend the better part of our lives trying to assure ourselves that our tales are already told, even if not yet lived, and that they have a happy ending. The discovery that this might not be so can, in itself, lead to a profound transformation. But the appearance of someone who has already taken the journey can bring a sigh of relief to the best of us. That is where mentors come in. They have been there before, and we greet them with awe, and above all hope.* (p. 27)

Carol provided a vision of the possible for Mike. She assisted him in his development as a teacher. Mike in return provided additional opportunities for Carol to reflect on her development as a teacher. Both were changed through this mentoring relationship and time will only tell the affect of this change on their future students and society.

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A CASE STUDY OF ALTERNATIVE ASSESSMENT: STUDENT, TEACHER, AND OBSERVER PERCEPTIONS IN A NINTH GRADE BIOLOGY CLASSROOM

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Overview

This single-site phenomenological case study at Suburban High School examined the perceptions of one teacher (Len) as well as his students, colleagues, and principal toward alternative assessment strategies and associated phenomena in Len's ninth grade biology classroom. Researcher perceptions are also included. Although there are multiple participants, the primary focus of this research was to understand and make sense of the world in which Len existed and where he viewed what he considered more meaningful assessment activities as alternative assessments.

The research methodology employed for this report was a qualitative descriptive case study using a phenomenological perspective, which describes the world experienced by the participants in their own terms. Questions guiding this study sought to determine: 1) what happened in Len's biology classroom as he used alternative assessment? 2) Len's perceptions toward alternative assessments and his rationale for using them; 3) how his students viewed his assessment strategies and the associated phenomena they experienced; 4) what students perceived as primary determinants of their grade; and 5) what Len's immediate science faculty colleague's and principal's perceptions were toward alternative assessment.

This study intended to contribute to the understanding of alternative assessment implementation by providing detailed, in-depth analysis of how Len, a 30 year veteran biology teacher, implemented and perceived assessment. Data reduced from interview transcripts, observations, and documents resulted in thematic perception generalizations of Len and the other participants toward alternative assessment at Suburban High School. Since it was the students who were being assessed, their thoughts and perceptions toward alternative assessment and their grades were also documented. After all, it could be argued that students' feelings and attitudes directly impact the success or failure of alternative assessment implementation. Similarly, since it was presumed that Len had significant contact and responsibilities with others in his school, there was also a need to discuss alternative assessment philosophies with his science teacher colleagues and the principal.

Analysis of the data was not intended to support or refute claims made in the name of alternative assessment. Rather, this study was intended to provide a vivid description of the situation studied and delineate potential implications for using alternative science assessment in a lasting and meaningful way. The following generalizations were supported by the data and those directly connected to Len were each redefined by him:

Case Generalizations:

1. Len's goals for, and perceived responsibilities toward, his students played an important role in his implementation of what he considered alternative assessment.
2. While Len used a variety of alternative assessment strategies, he still used the multiple-choice test format with essays as the primary source for individual student accountability.
3. Len's early and on-going informal assessments of students' abilities and attitudes played a key role in his perceptions of any individual's work ethic.
4. Len's involvement with professional development experiences had a direct impact on what assessments were used in his classroom.
5. Positive role models during the first few years of Len's career had a very strong impact on his perception of teaching; ultimately influencing what assessments he used from year to year.
6. "A work in progress:" Len's constantly evolving and continuing vision of his assessment future, coupled with his reflection on the level of his student's on-task engagement, fostered his acceptance and ultimate level of use of alternative assessment.
7. Arriving early to school, staying late after school, working weekends, expending large amounts of physical energy, and possessing other qualities of an exemplary teacher, facilitated Len's use of alternative assessments within his standard 50 minute period.

8. Len felt confident, yet alone and humble among his colleagues regarding his use of alternative assessments. Len felt he was a "Lone Ranger" regarding alternative assessment.
9. Len had philosophical visions of alternative assessment use and the role it played in the life of a teacher, "In the ideal world".
10. Past experiences of Len's students affected their current perceptions of assessment reality in his class.
11. Students worked toward learning goals only if an extrinsic reward existed; either in the form of points or grades.
12. Students felt they did best when they: worked in cooperative groups, took fewer tests, did projects, were active in class, and experienced less teacher talk.
13. Ninth grade students were more comfortable when the teacher evaluated them than themselves or each other.
14. Len's colleagues perceived alternative assessments as requiring too much time for the number of students they were responsible for.
15. Len's principal had only limited knowledge about alternative science assessment but felt her science teachers were "moving in the right direction."

Introduction

> "There is, I think, some mysterious unseen hand that shapes the consensus in American education. Almost overnight, assessment has become the focal point of a great debate about the purpose, shape, and control of American education."
>
> Marc S. Tucker (1991)

Berlak (1992) argued for authentic academic achievement from students that challenges the narrow view of academic learning represented in almost all standardized multiple choice tests today. Some teachers have always sought to assess their students by creative, authentic means within the confines of the classroom. But, much assessment during the past decade has strayed far from what many would consider authentic measures of true student learning (Berlak, 1992; National Academy of Science and The National Committee on Science Education Standards and Assessment , 1996; Stiggins, 1991 a, b, c; Wiggins, 1993 a, b, c).

The purpose of this research was to describe the nature and implications of alternative assessment strategies used in a biology classroom by one ninth grade teacher. As a result, this study describes the ways alternative science assessments were perceived and used by this teacher (whose pseudonym will be Len), perceptions of his role in assessment use, perceptions held by his students, colleagues, and principal toward alternative assessment, and perceptions of the researcher.

This phenomenological, single-case study examined a ninth grade biology classroom within its complex, cultural setting. The study was prompted by the *National Science Education Standards* (1996) and the enormous number of calls for the use of alternative assessments in science classrooms (Archbald & Newmann, 1988, 1991; Berlak, 1992; National Academy of Science and The National Committee on Science Education Standards and Assessment , 1996; Newmann, Secada, and Wehlage, 1995; Rutherford & Ahlgren, 1990; Stiggins, 1991 b; Wiggins, 1993 a, b, c.).

Alternative Assessment: A Definition

Most definitions of alternative assessment have similar notions that require a movement away from multiple-choice or standardized tests and a movement toward learner-centered assessment that relies on student generated responses (Wiggins, 1993 a). Alternative assessment 1) includes alternatives to standardized or traditional tests for finding out what a student knows or can do; 2) is intended to show growth and inform instruction; 3) is criterion-referenced, not norm-referenced test (it compares performance against established criteria or standards, not against a peer population; 4) is authentic when it is based on activities that represent actual progress toward a broad range of instructional goals (not just cognition) and reflects tasks typical of classrooms and real-life settings; and 5) may include teacher observation, performance-based assessment, and student self-assessment (Pierce & O'Malley, 1992).

The Current State of Science Assessment

Most science teachers at this time still continue to use some form of multiple choice test to assess and evaluate students (Stiggins, 1991c). To counter an over-use of traditional assessments, The National Commission on Testing and Public Policy (1990) recommended that testing programs currently relying too heavily on multiple-choice tests should begin a movement toward more alternative forms of assessment. More recently, ***The National Science Education Standards*** (1996) reform also suggested the need for alternative assessment methods.

Alternative assessments are likely to be more authentic or real in nature than traditional assessments, and therefore, be more closely aligned with the true goals that teachers have for their students' learning. The primary rationale for an increased use of alternative forms of assessment is that they are thought better at providing teachers and administrators with a more complete picture of what each student might know and understand about a science related skill or concept rather than comparing the knowledge of individuals to a standardized norm. Alternative assessments also are intended to help students begin to self-assess and take responsibility for their learning (Haury, 1993; Mitchell, 1992; Stiggins, 1991 b; Vandervoort, 1983; Wiggins, 1989, 1992, 1993 b & d).

What is lacking, however, are reports using any acceptable research methods that measure or detail the impact of such alternative assessments (Jorgensen, 1993).

Assessment Trends

Current reform movements in science education now make assessment a major issue (Jorgensen, 1993; National Academy of Science and The National Committee on Science Education Standards and Assessment , 1996; Tucker, 1991). Central to this issue is the movement toward higher order questions that provide a much greater portion of what a student might know and understand than has been the case in recent years. According to the *National Science Education Standards* (1996), students should be involved with exercises that closely approximate all the intended outcomes of science education. These alternative assessments require students to apply scientific information and reasoning to situations like those they will encounter in the real world or that approximate how scientists do their work. The assessment tasks should be similar in form to tasks they will engage in during their lives outside the classroom.

All alternative assessments are aimed at higher level thinking that requires more than rote memorization. Authors have used various forms of logical reasoning as they address the need for alternative assessment. Rationales such as constructivism, obtaining student generated responses, thinking of learners as individuals, and linking assessment to instruction have been used to support the use of alternative assessments (Darling-Hammond, Einbender, Frelow, and Ley-King, 1993; Glazer & Ogle, 1994; Haury, 1993; Herman, 1992; Jorgensen, 1993; Linn, 1994 a &b; Raizen et al, 1990; Sheppard, 1989 & 1994; Stiggins, 1992; The National Academy of Science and The National Committee on Science Education Standards and Assessment , 1996; Wiggins, 1989). Many examples of alternative assessment have indeed been documented (Dana et al, 1991; Darling-Hammond et al, 1993; Glazer & Ogle, 1994). But, amid the stories that detail the use of alternative assessment in science classrooms, surprisingly little can be found in the literature regarding the effects, impact, or implications of using alternative assessments. The research literature prior to this study similarly offered precious little in the way of describing the perceptions of teachers and students toward alternative assessments. Only one study was located that dealt with assessment in a high school biology class (Stiggins, 1986). A few reports were located that covered alternative assessments in elementary and college situations and those focused specifically on performance assessments or portfolio assessments as methods in particular rather than their impact on teachers or students (Anderson, 1993; Darling-Hammond, 1995; Reid et al, 1992; Sheppard, 1995). No reports were found with a phenomenological, conceptual framework as was the central focus of this research. In short, there is simply a research void in this area (Herman & Winters, 1994; Jorgensen, 1993).

Rationale for Research Methodology

Descriptions of Len's classroom rationale for using alternative assessment were based on qualitative, naturalistic research methodology. Specifically, phenomenological methods were followed as closely as possible so that any stated descriptions would closely mirror those of the participants rather than an outside observer; i.e. the researcher. Describing the classroom situation using the same terms as the participants provides their perceptions from the way they would describe it to others (McGee-Brown, 1994).

Qualitative research which has a phenomenological focus provides a very thick (Geertz, 1973), rich, and detailed description; one that originates from the participants. This type of study can be viewed as "purposive" as described by Chein (1981) or as "purposeful" by Patton (1980). Merriam (1988) further describes purposive sampling as being a way to discover and understand phenomena from a source known to provide the best possible information. Len was chosen for this study because it was felt that he fit the requirements for a purposive sample. Over a one year period, Len was identified as a teacher who was attempting to use a variety of alternative assessments.

A single site was chosen because it afforded an excellent opportunity to discover phenomena within the real world settings in which they occurred (Merriam, 1988). The principal goal of this study was to describe the perceptions of a teacher who uses alternative science assessments, his actions, the artifacts, documents, or tools he uses, thoughts of the other participants, and the description of the culture in which the assessments were used. Len, his students, colleagues, and principal were part of this cultural system and were considered as determinants for any actions that took place within the school.

A second goal was to begin with a predetermined set of questions related to alternative science assessment. As evolving working hypotheses emerged (Merriam, 1988), new questions were asked based on what the observations, data, and inferences suggested. As naturalistic research continues, it is not uncommon to change direction and ask new questions (McGee-

Brown, 1994; Merriam, 1988). It would be naive to assume all possible questions could be asked at the outset because of the constantly evolving system that occurs in any school.

Research Questions

The questions that follow guided this research from the outset and were used as a base for collecting the most relevant forms of data:

1. What happened in Len's biology classroom when alternative assessments were used?
2. What were Len's perceptions of alternative assessment and his rationale for using them?
3. How did students view the alternative assessment strategies they experienced?
4. What did students think determined their grades?
5. What were the perceptions of Len's colleagues and principal toward assessment?

The Setting and Participants

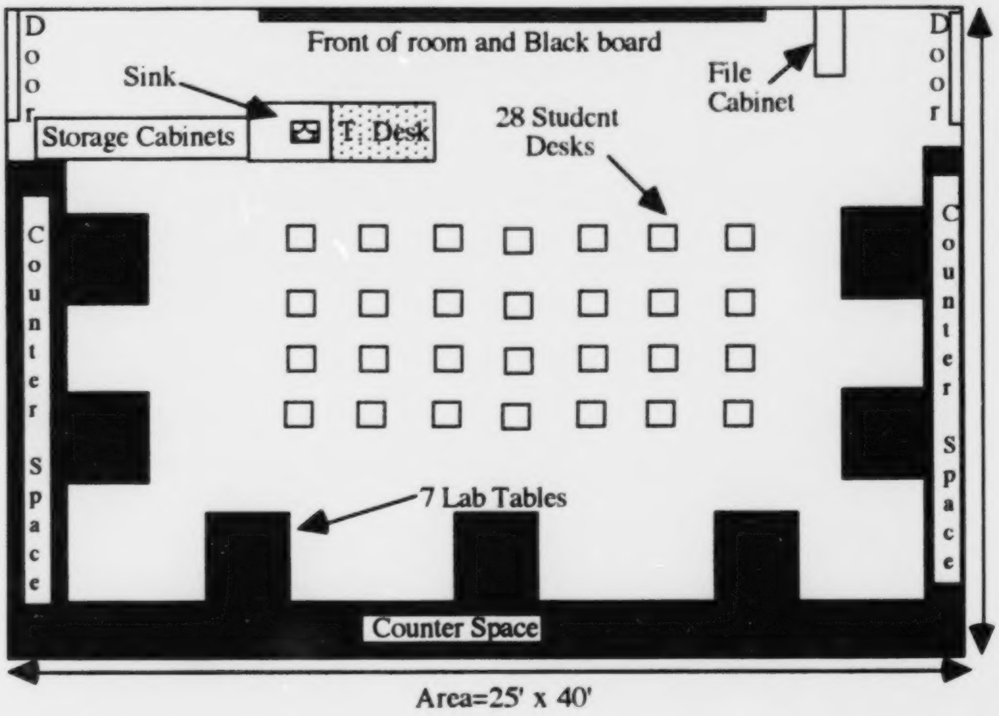
A Description of Suburban High School and its General Culture

The setting in which this study took place was Suburban High School (pseudonym); a grade 9-12 building located in the suburbs of a very large, midwestern metropolitan area with a human population numbering in the millions. Looking at Suburban High School from one of the four, 20 acre parking lots, one sees an attractive, three-floored, well maintained, and immense structure.

Most observations at Suburban High School were conducted within Len's classroom. The physical components and layout of Len's room changed only imperceptibly throughout the duration of the study. Len's classroom, which he shared with two other teachers each day, is approximately 40 feet wide and 25 feet from front to back. Student desks were always arranged in four rows of seven, unless an activity required their movement.

The key participants in this study were Len, his 56 ninth grade students in two *BioCom* classes, two chemistry teachers, one earth science teacher, one physics teacher, two biology teachers, and the principal. Although a small sample limited any possibility for generalizability, this case study research dug deeper and looked more broadly than would be conceivable with some commonly used quantitative methods.

Graphic of Len's Classroom


Door
Front of room and Black board
Sink
File Cabinet
Door
Storage Cabinets
T. Desk
28 Student Desks
Counter Space
Counter Space
7 Lab Tables
Counter Space
Area=25' x 40'

Overview of Study

This study consisted of Phase I and Phase II; the phases were separated by over two months. Phase I observations of the two *BioCom* classes occurred on two or three consecutive days per week for nine weeks during the first grading quarter of the Suburban High School year, September 15, 1995 to November 3, 1995. Monday and Friday visits were avoided to reduce the effects of anxieties on Len and his students that may have existed on these days. The length of each classroom observation for Phase I and II was 50 minutes as well as before and after class time. The two *BioCom* classes occurred in the afternoon in consecutive order. The seventh hour class met from 1:40 to 2:30 P.M.; the eighth hour class met from 2:35 to 3:25 P.M. As field observations were made, documents such as tests, mind maps, *BioLogs* (student logs/reflective notebooks), posters, video tapes of student presentations, and other forms of assessment that Len used were simultaneously collected as documents for analysis. Phase II consisted on revisiting the setting for two consecutive weeks in February 1996 to conduct more intensive interviews with students, make further observations, collect assessment artifacts, and clarify research findings with Len.

Data Collection and Analysis Techniques

Data for this research consisted of the following: 1) field notes; i.e. observations within and around Suburban High School; 2) in-depth, informal, e-mail communications and oral interviews with Len, 15 individual and six group interviews with students, and individual interviews with six of Len's colleagues and the principal that were all tape recorded and later transcribed for coding and analysis; 3) collection of documents and artifacts (McGee-Brown 1994; Merriam, 1988; Adler & Adler, 1994; Stake, 1994.

Data analysis was a very time consuming and complex process, which included making sense of interview transcripts, observations, and documents. All data sources required reading and re-reading between five and ten times in order to develop the clearest pictures of the condition in this school (Lincoln & Guba, 1985). Interview transcripts, observations, and documents were analyzed using the constant comparative method as outlined by Glaser and Strauss (1967) and naturalistic inquiry as suggested by Lincoln and Guba (1985).

Emergent, generalized statements from the findings were discussed with Len for verification and validation; a component of phenomenological research called member checking to see if the analysis was indeed in his own words (Merriam, 1988). Obtaining member checks maintains trustworthiness in a study. Upon receipt of the member checks from Len, the process of re-categorization continued (Lincoln & Guba, 1985; McGee-Brown, 1994; Stake, 1994).

Constant attempts were made to search for alternative explanations to any data analysis that began providing any theories. Because observations, statements, or similar pieces of data may be interpreted in different ways, it was the responsibility of the researcher to provide the most plausible explanation for any analyzed data (Marshall & Rossman, 1989; McGee-Brown, 1994). Triangulation was achieved by using all the various sources of data, member checks, and the expertise of the researcher as an instrument model (Merriam, 1988).

Discussion of the Findings

"Qualitative researchers seem particularly vulnerable to the tendency- and urge- to go beyond reporting WHAT IS and to use their studies as platforms for making pronouncements of WHAT OUGHT TO BE. A critical divide separates the realm of the observable from the realm of values about good and bad."

H. F. Wolcott (1990)

There is no absolute process or method in conducting qualitative research. Likewise, reporting findings in a qualitative study must be done in such a way as to remain true to the situation under observation and to express terms so that they relate mainly to that culture. This may be done in many slightly different methods because authorities in the field of qualitative research differ in subtle ways as to specific procedures for the processes in a qualitative study (Merriam, 1988; Altheide & Johnson, 1994). As suggested, data for analysis were collected within a specified number and types of cultural contexts, which is important for correct data interpretation (McGee-Brown, 1994).

Len's Story of His Alternative Assessment Practices

The following sections each tell a story from the perspectives of Len, his students, and his colleagues. Each section also contains some interpretations of the researcher, linking evidence from interviews, observations, and documents. Although Len's goals and thoughts are discussed somewhat separately, they should be considered as occurring simultaneously and in varying amounts within his classroom practices and setting. Each selected quote or description dealing with the study begins with a researcher assertion followed by a member check validation or refutation by Len.

1. Len's goals for his students played an important role in the implementation of what he considered alternative assessment.

Len's member check:

> *"Yes, I agree! Goals at a couple of levels a) at a thinking skills level (critical thinking, organization, communication), and b) at an attitude level that they will see science as a dynamic, creative, and 'fun' process."*

Interviews with Len and observations of his class indicated that what he "wanted for his kids" had a direct impact on what occurred in the classroom including what assessments he used. His goals were either implied or specifically stated during interviews. In addition, since Len defined alternative assessment as "more the activities [he] used in class", observations focused on his instruction rather than how the literature might have defined alternative assessment.

Len had at least 12 stated or implied goals for his students, which included: 1) student self-assessment/evaluation, 2) writing and reflecting in their *BioLogs*, 3) striving for quality in all work they did; 4) organizing information and presenting to class; 5) working hard; 6) students should respect and follow his directions; 7) students should enjoy his class; 8) group work; 9) creativity; 10) lessened focus on content; 11) creation of nurturing/warm environment, and 12) critical thinking.

Len's overriding reasons for using assessments of any kind were to 1) "get kids engaged;" 2) "to know the assessment is going to be a benefit to his kids;" and 3) "bring me new information about his kids that I didn't have before." These reasons led Len to mention a number of times that he often had done "the hottest thing at the time." With this comment, he was referring to what was being presented at conferences and workshops and what was being discussed in the literature. Regardless of the hottest thing, Len did not use these suggested ideas with his students unless they met his three overriding criteria.

Len's most important goal for his students were their self-assessments (he also called them self-reflections and his students mostly called them self-evaluations), "I want them to see what they've learned." Len was very interested in having them look at what they knew and understood. If they did not, he felt that he tried practical methods to get the students to a point where they could understand. Some of the practical methods of student self-evaluation were integral to *BioCom* where they were called "self-checks."

Len was also interested in "encouraging [students] to think about what they understood" and he "used the self-checks so the students could develop a strategy for filling in the gaps [of their knowledge]." Len similarly felt, "it was important for [students] to see and understand what they did not know, so they could do something about it." Although Len wanted students to understand their level of knowing, few students were able to articulate a strong understanding of this goal.

Student self-evaluation or assessment was also recorded in their *BioLogs*. The *BioLog* was one of Len's key alternative assessment strategies and was intended to contain the student self-reflections. Student self-reflections provided Len a window into their thoughts; helping him to realize his goal of student self-evaluation. He stated, "The log assessment has been the most effective strategy for meeting [my goal of student self reflection]. In having kids keep track of things, writing with some thought and keeping a good notebook, this [*BioLog*] has really extended beyond where notebooks used to be."

As Len's view of the student log evolved and grew, his belief in the power it had in helping kids better understand biology and his conviction to its constant use also grew:

> I have always been convinced that the notebook/log/journal thing is a really important tool. I always focused on the notes in the past; just the simple taking of notes. With the Quality Schools effort and the reflective writing that came with it, I [bought into it] and that's one thing I do differently now. I also assess on more than just 'I've got something written down for a day, and it's all neat, pretty, and well organized,' although [those things] are part of it.

> 2. Despite using a variety of assessment strategies, Len still considered the multiple choice test and essay the primary source for individual students accountability.

member check:

> *"Yes! For knowledge, content, and concepts. Again, just part of the 'total' student picture."*

On one occasion during the first grading quarter, Len passed out a 55 point test on Biodiversity, which was the *BioCom* unit they were studying at the time. The test was distributed after 7 minutes of teacher talk and students were given the remainder of the 50 minute period to complete it. Len described the 43 minute duration of this test as: "I guess it's pretty much a standard thing, given the amount of information they've worked with." No other rationale for test length was given. While these kinds of tests provided Len individual accountability, it was later discovered that this test, and those like it, caused a great deal of fear or anxiety in all but one or two students.

Len indicated that between 1965 and 1975 he was generally pretty traditional. He lectured on a regular basis, followed the text closely, and relied heavily on test and quiz grades. While the traditional test was still evident, Len indicated his use of these period-long tests had declined over the years. Even though he felt his multiple-choice test with essay the number one way of having students produce what they know about biological content knowledge, he was confident his reliance on them had lessened.

Len's rationale for his continued use of traditional tests came from his current educational responsibilities. He simply could not imagine "a better, more efficient way to obtain student accountability" than his test provided:

> I can't even imagine doing 28 individual projects [alternative assessments], truthfully! The multiple choice format is the only way [to get the accountability I want] at this stage of the game. If I did the projects, I'd be grading until I retired!

He continued: "only multiple choice tests give me what I consider individual accountability for biology." The actual test was scored using the heavily-used scantron machine in the science office. Len felt this kind of assessment provided the quickly-needed feedback for both him and his students regarding their content knowledge of biology.

Len could think of no other assessments that could accomplish what he felt important in this regard, individual accountability: "I still think there comes a time where each kid has to be accountable for what they've learned; a test does this for me." He concluded that there was also a "sanity factory [associated] with giving this kind of test."

Len's Grade Book

Throughout interviews, Len was asked questions about the processes he had gone through over the past 30 years and changes that had occurred in his grading practices. Indeed, Len's grade book closely matched what he described during interviews. During one conversation regarding the change in his grading practices, he provided a direct window into his assessments. He stated that 20 years ago his grade book would have reflected a much greater reliance on test scores for student grades. Although he was not able to produce an actual copy of the grade book from past years, his description indicated that his current grade book relies on test scores about 1/3 as much as it did in the past.

Len's First Quarter Grade Book

Assignment or Assessment	Point Value	Considered by Researcher/literature as possible Alternative (A) or Traditional (T) Assessments	Considered by Len as Alternative (A) or Traditional (T) Assessments	H=Homework T=Test Q=Quiz N=Non-traditional
BioCom Lists	10	T		H
People Search	10	A	N/A	N
BioCom Poster	15	A	A	N
Thought Questions	15	T	A	H
Knowledge Check	20	T	T	Q
Brine Shrimp Investigation	40	A	A	N
Personal Timeline	10	A	A	N
Biodiversity Test	55	Multiple-choice part=T; Essay part=A	T	T
Infomercials	50	A	"Very A"	N
Kingdom quiz	10	T	T	Q
Biodiversity Article	20	A	"Somewhat T"	N
Student Log	70	A	A	N
BioCom Science Congress Projects	60	A	Very A	N

Each of the assessments in the grade book was labeled as alternative or traditional by the researcher. These labels were then sent to Len for a member check to obtain his view. The comparisons between the researcher and Len were very similar and listed above.

3. Len's perceived role and responsibility as a teacher had an impact on what forms of assessment he used.

member check:

"Yes!"

Len was a biology teacher who felt strongly that students should understand nature and the problems that were occurring in the natural environment. At the same time, he knew he was dealing with kids and was constantly trying to find ways to help them learn:

> If I can get [students] to open up their horizons as to what goes into more meaningful learning, to get them to recognize that what we are trying to get them to learn has some meaning in their real life, and they can have input into decisions that affect their learning, and the assessment of their learning, I think victory can be declared!

Len felt it was his responsibility to provide experiences for his students so they would enjoy science. He thought by creating a friendly, warm classroom environment, he could help students become more open and communicate to each other more effectively.

Len also felt the need to show his students the criteria they generated mattered. Feeling the responsibility of getting students to develop their own criteria for projects fit his goals, he stated: "My motivation was to be fairer to kids. I would like them to feel that they are actually using what they came up with themselves." His role in this process was a provider of class time to let students develop the criteria. He thought that if he did not provide this time for the activity of students generating their own criteria, "it would go back to the same old thing of the teacher giving them what they need and what [the students] think is not important." While Len had students creating their own criteria, he felt it was "the instructor's responsibility to monitor the criteria they set so they don't make them unrealistically too high or low."

Len's perceived responsibility for having students produce quality fit with his interest in having students be accountable for themselves. Since Len was unsure of his student's previous personal accountability from other teachers, he was set on "having the buck stop here!" He felt that having students begin to think about quality was in their best interest.

Len also felt one of his roles was to keep "order and control" of his classroom so that a focus on the topic at hand could occur:

> I'm kind of an order person. I'm also better now than I was 20 years ago at dealing with voice. I do have a problem with class if I'm talking and I don't have their full attention. I get distracted by it. In a group setting, I need to have their focus. Now, when they're doing lab work, it doesn't bother me.

Len's perceived need to "bring the students through the curriculum" in a situation where he felt there "was volume learning going on" created the various roles that he realized in his class. He felt his role was to "plant seeds" because "his professional judgment told him what was best for his students." Finally, his need for student accountability evolved from a feeling that "unless someone takes a stand and demanded personal accountability it would never happen." His role, in part, was to make it so.

> 4. Len's early and on-going informal assessments of students' abilities played a key role in his perceptions of any individual work ethic and content understanding.

member check:

> "*Yes.*"

Len actively tried to make his class a warm, inviting place for students by his initial homework, in-class tasks, assessments, and assignments. They were structured to ease students into his class. While students were engaged in these tasks and participating in class, Len felt comfortable saying, "I know early on who does work and who doesn't." When asked again in Phase II about his belief in informal assessment of students, he remarked: "Patterns for students usually hold from early on in the year." Len felt comfortable in discussing the work ethic of any of his students and knew comfortably those students who worked and those who did not. Having students attain a good work ethic was also one of Len's goals.

While assessing students in an informal manner, Len looked for similar effort that he had experienced in life: "I guess I've always felt like I had to work hard, and I find it somewhat objectionable if a kid has got all this talent and won't work or does poor work." He looked for thinking and questioning skills, determined mostly during his large group discussions. Len also looked at students who needed help from him, keying into the problems any single student might face.

Len was convinced that daily student responses to his questions during his large group discussions told him the most about who was "getting it and who was not." While he felt this informal assessment was effective for him, he could not justify putting the information into a grade book or keeping notes on individual students. Even though Len felt he was gaining insight into all his students through discussion over an extended period of time, rarely did more than 6 to 10 students out of 28 respond on any given day. In fact, observations indicated that the majority of students rarely spoke at all. Despite this discrepancy in numbers, Len said:

> I really try to get my questions spread out some and contact 6 or 8 [students each day]. I feel like over the course of 3 days, I feel like I have a pretty good clue of where they are.

There were a few instances where Len was frustrated because his informal assessment of students did not match their real understanding, causing him dismay. One example occurred when students were given an assignment to "find an article illustrating how the loss of biodiversity caused or led to another event." After some discussion of biodiversity and the assignment Len responded in this way:

> You would think that I was speaking Kurdish or something! When we went to the library on Friday, I explained the task again. The questions [from students] started: 'I have this article that shows how CFC's affected the ozone layer. Is this okay?' or 'I found an article that explains what biodiversity is all about!' I couldn't believe it! The whining became deafening!

Len was dealing with 27 to 28 students in each hour. One of his goals during the first few weeks of school was "to get a feel for where the kids [were]". He felt his "intuitive feelings" provided him with proper feedback. He also spent time "watching and listening" to "the ideas and questions of students in groups." He was very attentive during these times and assessed the comfort levels of individuals and kept track of students in his memory.

Len's informal assessment of students was also tied to his responsibility to get students involved and engaged. He felt observing the students informally provided him with sufficient information to help them become more engaged than they may have been otherwise. Some of Len's students also felt that his informal observations had a direct impact on their achievement. One student commented:

> "[He looks for] your performance, your attention level, just how you act in class. [Len] sees someone really trying hard to understand something, coming in extra to get help. So, he might grade better on that kind of behavioral thing."

Other students stated independently:

> "He looks at our attitude in class, how we are at answering questions."
>
> "How much attention you pay him in class."
>
> "How we work together, if you're not goofing off. That looks good to him."

Although both Len and his students felt informal assessment was integral to the classroom environment, Len also admitted he could never really be sure of what was going on inside "a kid's head." Len did, however, feel certain about one matter: "By the time I have a kid in biology class for the year, I have a pretty good idea about that kid." Len felt "the patterns [of kids] really do hold," which was his rationale for not giving difficult tasks early on. Easier assignments early in the year provided Len with mental pictures of many of his students so that he was able to see who he might need to be concerned about.

> 5. Len's involvement with professional development experiences had a direct impact on what assessments were used in his classroom.

member check:

> *"Yes!!!"*

It was not difficult to understand how Len's professional involvement and affiliation aided in his use and adaptation of alternative assessment. Not only was Len involved with *BioCom*, a new curriculum containing alternative assessment, but he had also presented his methods of alternative assessment at the NABT conference during this study.

The two most important factors that emerged from Len's professional involvement were his recent awareness of cooperative learning strategies and his constant quest to find engaging activities for his students, which resulted in his increase use of alternative assessment:

> From 1985 to 1995 I became involved with cooperative learning strategies and had students begin to play a role in assessment [of self, and of others]. I learned strategies to make group work more effective and students individually accountable as well. I think this was the birth in my brain of authentic assessment strategies. We also became aware of Dr. William Glasser's Quality School, and again this helped to refine strategies for students to begin to look at what THEY wanted, what THEY were doing to get it. I also took some course work on motivation, developing student responsibility, questioning strategies and attended several critical thinking conferences. These all helped to form my teaching style. STS biology became a buzzword and that rang the bell for me in that I was on the mark in making those links between course work and real world science. It verified that the thought processes were far more essential than the content.

Len went from merely attending presentations at conferences to presenting at them himself, enjoying it immensely. He felt the most important change for him came in 1984 while he was attending a genetics workshop at a major midwestern university:

> What I found out was what I was doing very much in tune with those people who were getting the recognition, or being recognized as being outstanding teachers. I went Oh! You mean I'm not so far off base? That's really where the biggest growth and biggest jump in willingness to try to pursue things like [these different assessment ideas] started to happen.

Len's knowledge of new assessment trends did not always guarantee they would be used with his students. He stated, "There are a lot of things teachers have to do and [I] always get torn between doing what's easiest and doing what the current trend is or what the right thing to do is."

> 6. Positive role models during the first few years of Len's career had a very strong impact on his perception of teaching; ultimately influencing what assessments he used from year to year.

member check:

> *"Positive role models during the first few years of Len's career had a very strong impact on his perception of teaching. This ultimately influenced his views on using a variety of assessment. This feels more accurate to me."*

As Len discussed his views on teaching, learning, and assessment, he would make reference to the mentors he had during his first few years of teaching. Len's two role models, Mr. West and Mr. Mouvers, exerted a strong influence over him. Mr. Mouvers was especially significant to Len:

> Mr. Mouvers was the guy I looked to as being somebody I would strive to be like! He was always trying to bring the real world into the classroom. He and Mr. West started a class called 'Social Implications of Biology' years before STS became a buzzword.

Len commented that his start with these two individuals. He emphasized how each was able to get him thinking along the lines of STS.

Len's two role models had transferred to other schools early in his career. This fact did not deter him from developing a team-teaching approach to science with the social studies teacher. Len indicated that the work he had done with this teacher demonstrated how he could "throw a thought to the kids" in a more open ended way.

Although his mentors had left the school, they had instilled a tendency toward hard work. As a result, the energy level Len felt was needed for teaching and his habit of expending energy were developed early:

> Once you get into that mode of keep hustlin'! or Keep movin'! it becomes a habit. I think if I had gotten into a mode where it was all planned out, I probably would have followed that. Although, I think I would have gotten quite bored. You know, it's part of what you're used to. When I got here I was around these really good teachers, so I had to start hustlin' to keep up with these guys who [were] doing a great job! Then, once you start doing it, you don't want to fall back!

Observations indicated that Len continued to physically hustle after 30 years of teaching. Advising a weekly ecology club, spending 2 extra hours at school each day, and constantly trying to find new ways to engage his students occupied much of his time.

> 7. "A work in progress." Len's constantly evolving and continuing vision of his assessment future coupled with his reflection on the level of his students' on-task engagement, fostered his acceptance, and ultimate level of use of alternative assessment.

member check:

> *"Len saw assessment as dynamic as he couples his reflection on the level of student on-task engagement with his constantly evolving and continuing vision of his assessment future."*

When it came to assessment strategies, Len considered himself "a work in progress." He was quite aware that the assessment strategies he was using were not perfect. However, he felt they were better than what he had used in the past and he was constantly adapting them as he went along. He spoke of change in his assessment that began to occur between 1975 to 1985 and how he currently reflected upon aspects of assessment primarily in his 35 minute car ride to and from school.

Len reiterated that when he spoke of alternative assessments, he was talking about the activities that he had students doing. He re-emphasized that his goals were "student engagement and fun." He felt the assessments (activities) should be fun because "they engage kids more if they were." The alternative assessments Len used also provided him a "clearer picture into students on task engagement." He felt that using the different forms of assessment "allowed different kids to express their worth in different ways." As Len thought about the assessments he used, he adapted them to fit each class. For example, using one form of assessment permitted Len to witness his students' previously unknown abilities. He stated: "I didn't realize the visual part [of assessment] was so important until I started doing it. Until I started having kids turn these things out, I didn't know how talented they were."

Len thought that what he was doing in terms of assessment was useful for him and "he was on the right track with research and a good deal ahead of his colleagues." He based his comparison with his colleagues on brief interactions and discussions in the science office. In short, he "felt pretty good about where [he] was."

Despite Len's feeling of being ahead of his colleagues in terms of alternative assessment use, he was not sure about how much students would learn using any different form of assessment, but he felt, "everything says the more different senses you get involved in the learning the more likely it is to be retained." Although Len felt he was headed in the right direction in terms of assessment, the assessment strategies he used had different effects in both classes, which caused him to reflect on his teaching.

Len was confident he would continue to change and adapt in the future. His intentions were to "keep refining" what he was doing so that his students could see what he was trying "to shoot for and what they should produce." As his refinements continued, he humbly stated the changes he saw happening over the years:

> Am I approaching my vision? Approaching some ideal? I think I'm doing what I set out to do. I gauge my kids, I watch my kids. I'm judging 1) are they doing what I asked them to do? 2) are they interacting with each other in a positive way? 3) are they picking up the content?, and 4) are they having some sort of problem that I can see?

Ultimately, Len felt assessment should grow to a point that students could effectively use it for themselves. They could see what they knew and didn't know and hopefully pursue ways to fill the gaps in their understanding. Len felt confident and "pretty good that [he] had grown in terms of assessment."

> 8. Arriving early to school, staying late after school, working weekends, expending large amounts of physical energy, and possessing other qualities of an exemplary teacher, facilitated Len's use of alternative assessments within his standard 50 minute period.

member check:

> *"Len feels it requires time outside of the regular 50 minute periods, and daily teacher routines, to create meaningful assessment strategies, reflect upon what skills the students are exhibiting, decide what needs to be focused on next, and plan how to include student input into the assessments."*

Observations indicated that Len worked on assessment strategies and evaluated student products both during and after school hours. Len perceived his use of time out of class as necessary and he felt the he was "still relatively new at [assessment]." Working on his assessment ideas out of school helped him change and he mentioned that "if [he] had not changed, [he] would have gotten bored."

Len's openness to change also led him to using cooperative learning. Since much of his alternative assessments required group work, Len assessed students with questions as he walked from group to group. While walking around to each group provided him with informal assessments of his students' abilities and understanding, he still found the action of moving from group to group very physically demanding. Conversely, he found "it easier to stand up and talk to [students] from time to time."

At the end of each day, Len indeed had an exhausted appearance. Interviews at the end of each school day during site visits indicated Len's energy level had dropped noticeably from the morning. Upon one occasion, he appeared extremely tired. After being questioned about how he felt physically, Len remarked, "Today was pretty tiring and I've got a lot of stuff to do before tomorrow."

Len described his instruction while students were in groups as "causing a lot of wear and tear [on him]. It's a lot harder to get up and get around." He continued to speak about the amount of physical energy required for him to do what he felt was right for his students, that is, getting them in groups to work on projects, which were some of his alternative assessments. Len felt that getting students involved in groups caused "action that drained [him]."

It was easy to see that Len did indeed, as he described, "work his can off!" He required at least one weekend day and most late weekday evenings to create and adapt the assessments he used. One of Len's interests at home was being creative in the development and adaptation of activities and assessments. He offered, "I would sooner sit down and create new activities than I would grade a stack of papers." His creativity was able to be used at home and he enjoyed the process. *BioCom* also provided alternative assessment ideas that he felt had strengths and weaknesses that he changed to fit his needs.

Len commented about factors in his personal life that enabled him to be creative with assessments and develop new activities while he worked at home. He spoke of the support from his family as being very important in allowing him to continue: "I could not do the things that I do if my wife wasn't cooperative and my son wasn't cooperative, because that's where more of my energy would have to go."

Although Len reaffirmed that he would continue to use and adapt his assessments, he admitted he had to find more time at home. He spoke of a goal he had been developing over the past few years:

> One of the things I have to do, frankly, is to find more ways to use less time. Because of all the time I was spending on school work, I was finding that I wasn't doing much at home. I saw that [my family] wasn't going out and having some fun, or having time for the hobby type stuff: [I] just didn't do it! I've been spending all my time up there on that computer or grading papers or creating activities, or watching video [assessments] from students, or at school teaching. I see other [science teachers] going home at 3:30 or 4:00 p.m. and I'm here plugging away at 5:00 or 5:30. Then I go home and do more [school] stuff.

Observations matched almost perfectly with Len's beliefs of what his actions were. He was at school at least one hour early and indeed, stayed daily until 5:00 or later. Visits to his home indicated much time spent on school work. Len had an office within his house where his computer sat on a desk, surrounded by curricular ideas, exams, and a plethora of other teaching resources.

Although Len wanted to "find more ways to use less time," he felt there was ample time to use alternative assessments. "The time is there to do alternative assessments, it just needs to be rearranged. Despite some of the barriers to an ideal teaching situation, there seemed to be many indications that Len spent much more than 40 hours each week on educational activities, of which development and adaptation of the assessments was a part

Note: Member checks were not able to be obtained for generalizations 9 through 13. The following five generalizations were based on data and researcher interpretations alone because students were only available for limited times.

9. Past experiences of Len's students affected their current perceptions of assessment reality in his class.

Assessment meant "evaluation" to almost all the 9th grade students interviewed during this study. Furthermore, evaluation meant grades. While Len's grade book reflects a multitude of assessments of differing value, most students felt Len's tests were the primary determiner of their grades. Interestingly, those student whom Len would consider as having the "most talent" or "the greatest ability" realized the *BioLog* was "worth more" total points, yet focused a disproportionate amount of energy on the test. Ongoing observations and interviews indicated that Len's students had considerable experience with tests being primary determiners of what they considered evaluation leading to grades.

Most students defined assessment as either "teacher evaluation of you" or "what you do to get a grade." Though Len used a variety of assessment to determine students' knowledge or abilities, students had mixed views about the goals of Len's assessment, what counted most, and what they knew from past experiences.

Overall, students' views of assessment reality had no common thread. Assessment experiences students had in past years were markedly different between individuals. For instance, depending on which junior high a student came from, they were either familiar with multiple-choice tests, essays, projects, or worksheets as means of assessments. A few students had some experience with logs while others had never heard of a log prior to Len's class.

However, the factor that seemed to hold true among all student respondents was that Len's tests were very difficult for them compared to what they were used to from prior science classes.

One of the most interesting aspects of students' perceived reality was their focus on Len's tests. Observations and student interviews indicated that the majority of student energy was spent taking notes for the single test and quiz during the quarter. Although the total 55 points of the test only amounted to 16% of the grade, many students indicated they spent untold hours writing all possible notes into their logs. When asked about the reasons there was such a focus on these test when it was not a large percent of the total grade, one student commented in a surprised voice; "Oh! I guess it's just that other teachers grade tests more than anything else." It became apparent that only as students began to think about the ways in which Len really assessed them did some begin to broaden their perceptions of the assessments they were experiencing.

10. Students worked toward learning goals only if an extrinsic
reward existed either in the form of points or grades.

There was strong indication that students who cared about their grades focused on studying their notes for tests so they "get a good grade." There sole purpose was not to learn the material for the sake of learning, but to get "enough points for a good grade." Likewise, when given a scenario in which all grades were removed from assessment, all students interviewed stated the quality of their work would "go down" if grades were removed. Even the students Len considered most academic said they "wouldn't try" if their work was not evaluated with points assigned to it:

Researcher: "What would it be like in a science class without grades?"

Student It would make your quality worse because you wouldn't worry about it. You wouldn't worry about grades because there wouldn't be any point for grades. You'd probably just want to get through [the class], and want to get the class over with. You'd always be worrying for the bell to ring. You'd just want to get outta there!

Student I don't think we'd try as hard [without grades]. We wouldn't pay any attention in class. You just don't have the time to bother with stuff that doesn't have any points. Points are there to make you learn. It's not a bad thing to have points. It keeps you going!

Students view grades as levels of "smart" or "dumb". Most commented about those who received "As and Bs" as "smart" and those receiving a "C" or lower as "dumb." One student took this notion one step farther and related views that parents might have regarding grades. This student believed parents respected the grade given by the teacher; "what the teacher thinks is what the parents are going to think. If he gives you and 'F', then you obviously don't know this stuff!" Although Len told his students; "there is some value to learning", he felt it really was not believed by his students. He thought, "to have the kids [learn] because you say 'this is good for you!' It's just not going to happen!" Len was unsure of the reason why his students actually worked in class but remarked about the motivations that his students might have had. He thought some of his students may "have had a change in attitude and began to like learning." He also thought that some students might be "deciding to jump through hoops just to get [him] off their back for the grade." Whatever the reasons, students had for participating, Len was not sure of what they were.

Len's rationale for grades was equated to "paying [students] points like a salary." The trick he said, "is to make the awarding of points understandable. Then, they can come to me and discuss if they want to accept it or reject it." With most of his assessments, Len used rubrics on which to base a student's grade. Although he admitted "getting stuck" on some criteria, they were nonetheless used to assign the points for the grade. Len ultimately felt that most students would "try to get by doing as little work as possible anyhow" and he believed that only a small portion of his students actually put forth effort "because it was good for them."

> 11. Students felt they did best when they: worked in cooperative groups, took fewer tests, did projects, were active in class, and experienced less teacher talk.

Len had a vision of what kids should and should not be doing while they were in groups:

> One of the things with cooperative learning is that you can't just throw kids together. They don't know what they're supposed to do. They're just going to be together and screw around. So when you do true cooperative learning, they've got roles they're supposed to carry out and then they're supposed to be checking on each other, and that's where there is supposed to be the individual accountability as well.

While Len focused on the assessment regarding the collaborative nature and task orientation of group work, the students saw it from an enjoyment perspective. Almost every student interviewed spoke of the positive aspects of working in groups. Indeed, a majority of times that students were observed in group work during class, they demonstrated many on-task behaviors including: discussing the project at hand with each other, organizing thoughts, or working on completing a poster, drawing a model or similar activity.

Many students felt they worked best and learned most when they produced projects and worked in group at things. Many also felt that they were best able to show what they knew and understood about biological concepts via projects presentations. Each of the following responses is from a different student responding at different times to questions dealing with times they have positive feelings and attitudes in Len's class:

Student: Group work is best. We can talk to people about stuff and they'll understand it. I like the Congress. Our group had so much fun with that! It was the best project that we had in science class.

Student: Our cell factory was fun, where he had us use our creativity to design how the parts of the cell factory worked. So you had to understand the cell before you could made a factory. So I like know you really had to understand the cell before you could do it.

Researcher: What's different about building a model and taking a test?

Student: When you're doing a model, you know exactly what is expected of you, like the cell factory. When we take a test, it can be on like a lot of different things. The test you study the night before and then you probably forget everything the day after the test.

Student: Like when we did the cell factory, I really understood the parts when we did that. When you put things in words that we know. I really understood it, I was sure about that. All the cell parts -- we had to make a poster of a cell factory and explain how everything worked.

Student: I think I like projects better. I think tests will show you what you know, but projects will let you apply it. You can know something and you can see how things are affected. Tests will tell you the same things, like what you know and what you need to go back and look at, but projects are a lot more fun, more hands on than circling a bubble or something.

Student: I'm glad we have a lot of projects! They are a lot more fun to do.

Some students spoke of projects and group work as definitive in demonstrating their knowledge of a subject.

> 12. Despite Len's goals of student self-assessment, the majority of students were either uncomfortable assessing themselves or more comfortable [confident] in having Len assess them instead.

Len felt it important for students to begin to take responsibility for their own learning. He employed at least four methods to accomplish this: Student self-reflection in their logs, group evaluation, *BioCom* self-checks, and having the students develop some of their own criteria for projects. However, only a few of those students interviewed from the 7th hour class were able to articulate what Len's goals were or saw similar merit in assessing themselves. Even the most talented students were not excited about having to evaluate their friends when the time came to use the criteria they had developed.

Len had given written expectations for self-reflection in the student logs early in the semester. These expectations reflected Len's goal for student self-reflection. Students were to write down what they learned or felt about class daily. However, the majority of students did not write as Len expected. He suggested a possible explanation for the student concern was that, "they may have never done this before."

Both classes had a team of four judges. As all other groups worked on their Biodiversity Infomercial, the judges moved from group to group collecting different project criteria from students. The end results were student developed rubrics in both the 7th and 8th hour classes.

Students looked favorably upon development of their own criteria. Both classes of judges offered mixed emotions on the power that was bestowed upon them. A few student judges "liked it! Who is better to know about what we are capable of than us?" Others did not because of the light hearted "judge bashing" that occurred after scores were rendered.

Following are some actual examples from student criteria generated from both classes:

Judging Criteria: Period 7

Scale
None Very Good!
0 1 2 3 4 5 6 7 8 9 10

1. Basic Knowledge of Kingdom:	7-10	answered all questions	______
	4-6	answered some questions	______
	0-3	answered few questions	______
(members, key features, uses, characteristics)			
2. Explanation of Information:	6-10	good details	______
	0-5	few details	______
3. Creativity:	7-10	got class attention and kept it	______
	4-6	satisfactory	______
	0-3	dull and boring	______

Comments:

Judging Criteria: Period 8

Points: 0-5

☐ Creativity	High:	original concepts
	Low:	unimaginative
☐ Amount of information	High:	Plenty of new information
	Low:	repetitive and minimal
☐ Time	High:	Between 2 & 3 minutes
	Low:	Too long or too short
☐ Speech Clarity	High:	Loud and Clear
	Low:	Quiet and mumbles
☐ Effectiveness	High:	"Coveys" correct info, persuasive
	Low:	Does not portray a worthy "product"

No visible problems were observed or spoken about by students while rubrics were being developed. However, when the time came to evaluate the group presentation, an uneasy feeling became clear in both groups of judges. The student judges were very uncomfortable evaluating their peers. The personal bonds that existed at that age were stronger than the objective criteria they had just developed. Students commented that they felt uncomfortable grading their friends because of the "hard feelings" that might occur. One group did in fact, accuse a judge of "being too hard on [them]" in front of the entire class. To avoid further student embarrassment, Len stepped in and discussed the notion of consistency. That is, he told the students that it was "OK to be conservative as long as that person was consistent throughout each group." This sounded like a fair explanation, but nonetheless, the judges felt uneasy. One student suggested, "it might work if they had more than four judges" but did not suggest what a critical number would be.

Despite some student argument over their scores, Len was confident that his students would begin to understand quality and quantity based on criteria: "As they go along, they should come to realize that there will be more and more evidence. There are, I'm sure, some students who haven't quite got the evidence part yet. The way I assess kids is to give them a chance to see what goes into making a decent student or what should go into making a decent student. I guess since I try to look at a more total package, I want them to look at that as well." Len further articulated his rationale for having students develop their own criteria:

> Ideally, what I want [student developed criteria and self-assessment] to be used for is for them to understand where this is all coming from! That it is not some sort of magic. That it's not the person at the front of the room that is doing all the determination, that if they bother to use their heads, they can pretty well determine what they are going to be getting, what their grade is.

When it came to self-evaluations, most students interviewed felt they were "harder on themselves than what [Len] would be." As one explained, "a lot of times you put yourself down. You might not think you did well, but other people might think that you did really good." Despite the fear of a negative feeling toward the judges from their peers, they were able to articulate the benefits of creating their own criteria: "I think it's a good idea. Because the teacher might have higher expectations, but we're like, younger and we know about our age what we should be able to do. So, I think it's a good thing." This same student expressed self-grading [assessing] as having positive outcomes:

> Ideas from our grade level are good. Looking for things that we can achieve. We don't know everything our teacher knows and we never know what we're getting graded on. I think it's a good that we have a chance to grade ourselves from things we made up that are important to us. You have a chance to make things more comfortable for people that don't like to get up in front of groups and give presentations.

It should be noted that only the more articulate 9th grade students were able to verbally express the benefits of generating their own criteria. The students best able to explain what they felt were also those who spoke most freely and often in class and remained on task the majority of the time during group work.

13. Len's colleagues perceived alternative assessments as requiring too much time for the number of students they were responsible for.

Since Len had both personal and professional contact with some of the science teachers, it was considered important to this research to ascertain their beliefs about alternative assessment and to see what impact they may have had on Len or he on them. While Len was never observed discussing anything formally regarding assessment with his colleagues, he indicated briefly discussing assessment ideas with "one or two individuals from time to time." He also had the "feeling that he was ahead of [his] colleagues in terms of assessment because of conventions and things like that."

A few of the teachers interviewed made statements regarding Len's attempts at alternative assessment. Keith, the ChemCom teacher said, "I know I'm no where near where Len is in terms of assessment." Another biology teacher said, "I know I should be doing more, but I just can't bring myself to do the subjective types of assessment that Len does."

The colleague interviews resulted in a list of barriers to their use of alternative assessment including: lack of time in concert with too many students, training/further education, support for district, sharing classrooms, the personal factors of not willing to take risks or try new things, personal constraints, and "too much curriculum to cover already." The perceptions of the colleagues were most strongly centered around a combination of having "too many students and too little time to even try anything new."

Janet was the busy principal at Suburban High School. She quickly admitted to having only a "limited understanding of alternative assessment strategies in science." However, Janet felt her district "was trying to become better at alternative assessments." She was most familiar with the English faculty, who were using portfolios. Janet thought her science staff was growing, but was unable to express any knowledge of assessment practices currently being used in the science department.

Note: The final two generalizations relate directly to Len and therefore, will have member checks.

> 14. Len felt confident, yet alone and humble among his colleagues regarding his use of alternative assessments: He felt he was a "Lone Ranger" at times.

member check:

> *"Yes!"*

While Len was trying new assessment strategies, he never mentioned his colleagues as doing a poor job when it came to assessment strategies they employed. Even his strongest hint of having more knowledge than his colleagues came as he stated: "I feel I am ahead of my colleagues because of conferences and such." Never once did Len speak poorly about his peers, only that "some were doing the best they could," and "some were stuck in a rut." He continued:

> You still have that 'tried and true bunch'. Most of the teachers have degrees and have gone through these programs and were successful at the old methods. Good memorizers, good content people.

Regardless of what his colleagues were doing, Len felt confident in all the new assessment strategies he tried because they both satisfied his "goals for students" and were "fun." Despite his confidence, Len was honest about his feelings about his knowledge of teaching:

> A lot of times I feel dumb if you really want to know the truth! (laughter) Some people think they know the answer to everything. I never felt that way, I always felt a little stupid! I feel the same way about teaching. I never felt that I quite have all the right answers, so I just kept out there, doing this or that. Part of it is an uneasiness that I'm not reaching as many students as you could, or, it's a part that I'm trying to do the best job that I can.

Even though all his colleagues felt he was a "great guy", "exemplary teacher", and "not a finer educator could be found," Len was aware of some inadequacies regarding the extent of his abilities and effectiveness.

Attending conventions was a first step in demonstrating to Len that he was actually a leader in alternative assessment practices which gave him confidence to go on. However, "spreading the word" within his own faculty was not one of his priorities. Len was respected a great deal by his colleagues, likewise, he respected most of them and would only consider offering suggestions if asked:

> I'm not much of a salesman to try to make others do it the same way so where there may be people in the department that might benefit by it, I can show [my colleagues] what's out there and they can choose to pick it up or not. I don't know if [forcing] would be all that effective with the kind of people we have around here. So, you can only show them what's been working for you and I feel pretty good about that.

Months later, Len had similar feelings. He commented on how he, indeed, tried to share his ideas with others:

> I'm not much of a crusader. I don't feel comfortable telling others 'I am right and you're not.' Or, 'Isn't it time to change your strategies'. I share practically all I have and do with those I teach with (save a "leech" or two). I do get the reaction 'I don't have the time' or 'I can't get the kids to...' or 'I wouldn't know how to grade something like that' all too frequently, but I figure they might get inspired some time. I also think that there are those that actively don't WANT to know because they see it as meaning more work for them to have to re-tool in some way. I do know that I am generally in better control of my classes, have better luck with the more 'difficult' student, am generally happier with my kids, and what I am doing than, those that are still in their rut.

Len not only saw his field testing of *BioCom* during this research as change, he felt he had been making progressive and positive change his entire career. Knowing his limitations, he remained humble throughout the duration of this research as he reflected many times:

> I am doing some things. Am I doing them as well as I could? Probably not. I think I'm "a work in progress." I think back somewhere that that's what I was. Nobody was perfect but in fact [I was] always working toward that. It really fits my story.

Because there was little time for formal idea sharing, Len was virtually alone in his use and knowledge of alternative assessment.

15. Len had philosophical visions of alternative assessment use and the role it played in the life of a teacher: "In the ideal world".

member check:

"Yes -- and really (and maybe more importantly), in the life of the students too."

Len had definite ideas on what he felt was necessary for successful implementation of assessment strategies similar to what he was using. Len expressed his feelings this way:

> If you are going to sit down for the first time and really work through new assessments, how they work, what are they about, it takes time to work your way through that. If you're going to create an activity from scratch, it takes time. You have to have time to learn everything you are going to use. So, as you create the assessments and you create the assessment documents, that takes a world of time! So, if I didn't have that time to sit down, I wouldn't be doing it. I sometimes feel a bit overwhelmed at the number of different things that do go on. There are teachers that are not risk takers who would say, 'Oh, I won't do role playing because I haven't done that before.' How the hell are you going to do it if you don't give it a shot? How are you going to be willing to give a shot? Part of it is maybe, I have been willing to settle for less than perfection at times, which in some people it's harder than others. If you can get that kind of mind set then, you can be a risk taker in a lot of respects, because you are doing the best you can. Now, 'can you do it better the next time?' 'Yeah! Now that I've seen it once, I can do it better the next time!' But, you did it best right then.

Len felt he was a risk taker and also felt many other teachers were not. Along with taking risks, Len suggested four ideals that most teachers would need to begin to use alternative assessments in a meaningful way. He felt teachers needed their own room and a greater amount of time to plan, try, reflect on, and adapt assessments. Block scheduling may be an option for time, and have fewer students per class. Len also felt teachers needed to "perceive alternative assessments as less work rather than more." Len believed the science teachers he knew would not try any new assessment strategies if they saw them as more work than what they were doing. He and his colleagues gave many examples of their busy work schedules and the overwhelming feelings of responsibilities they often had. While Len found ways to offset barriers to alternative assessment implementation, he was very confident that others would not be as adventuresome as he in terms of the assessment strategies he was currently using.

When Len considered his own situation, he realized the limitations to both instructions and assessment that came as a result of sharing classrooms with other teachers. Len pushed a small movie projector cart to and from two different classrooms. Each day the cart contained what he needed for that day's lesson. Len dreamed of a day that he could say; "No more carts for us old farts!"

While Len felt teaching from a single room and having teachers perceive alternative assessment strategies as requiring less work, time and class size were factors he considered most critical for the majority of teachers to "buy in." Len first discussed how little time he had to share ideas with his colleagues:

> Time just isn't there! You know we have official meetings. The after school stuff is about the only time and there's not much of that because people have all these other responsibilities. In our district, all that's talked about now [regarding assessment] are the mandated state science rubrics. They're a pain in the ass!

While not able to talk to his colleagues about assessment on a regular basis because of time constraints, Len also felt he even had little time to reflect on his own ideas:

> I was just thinking today, about a simple thing, having my own time to reflect on what's going on. And even that simple thing of sitting down and reflecting. I have a book that I keep assignments in. I'm three days behind on that already! I don't find myself wasting time, it's because everything is always going on! Then when you change classes, you're trying to get some things done or you try to talk to an occasional friend or two, then you have clubs and you have work when you get home and try to do that kind of thing. It's hard! It's really hard! Let alone sitting down thinking on what I want to reflect on what I'm doing. It's just a real difficult thing to do. Maybe I could get by on three hours of sleep instead of four! [laughter] It's just the way it is around here! Sometimes I get 35 minutes on the drive to work that I use for reflection.

Len said he often thought at length about his use of school time and the way it was scheduled. He was able to explain his thoughts on both his feelings of time and how time might be better organized to allow teachers to assess students in a more meaningful way:

> I don't think I've really changed my viewpoint about alternative assessment and time. The role playing, hearings, etc., do require more time and would benefit from larger blocks of time - to reach closure or some natural break points, but the anecdotal comments, checklists, group, and self-evaluations, etc., do not require extended class periods. sometimes I think it would be nice to have some individual interview time too. Don't forget I've been "geared" to 50 minute periods for almost 30 years, so I've learned to just do it - 'rushing' seems like a natural way of teaching life. It's just more thinking time, more time! If you're doing projects, 7 groups takes longer than 5 groups.

Len continued by offering block scheduling as a viable option. He indicated his science department chair (Keith) had given him an article that provided him with plausible ways of restructuring time in schools:

> Block scheduling could also allow for some better interdisciplinary and alternative assessment focus as well, because kids could be doing the related math, related reading, and creative research, etc. in other classes. You could really build some interesting problem-based learning scenarios. Keith gave me an interesting article on [block scheduling]. Strangely enough their comments parallel mine nicely, only in a much more detailed manner. They also have some concrete examples. It was: ***Using Time Well: Scheduling in Essential Schools*** by Kathleen Cushman from a publication called HORACE, put out by The Coalition of Essential Schools. [Volume 12, Number 2], November 1995.

Although Len felt time was a critical component for successful alternative assessment use, his biggest concern was still over class size. Len had 28 students in most of his five classes. Yet, he felt he successfully implemented a number of alternative assessments. However, he was not as sure about other teachers wishing to try, and simultaneously be successful with alternative assessments with such large groups of students:

> In the ideal world, it would be nice to have one less class, it would be nice to have four rather than five as they are in some schools. It would be nice to have classes of 20 or 22, we have classes of 28. It makes a big difference in how you are willing to assess! If you have fewer kids and fewer assessments, I think you have more of a willingness to use some of the alternative assessment strategies that would require more time of you. The principal will tell you 'there is no real hard data that small class size makes a difference.' Smaller classes just makes a better atmosphere. Period! The kids have a little more room, they can spread out a little more, you can get to the same kids more than once, you can get to their lab group more than twice in a class period. It makes a difference, I don't care what anybody tells me! I can see it.

Len supplied a practical example of the time required for using one alternative assessment he used:

> I've got seven audio and video tapes per class and it's going to take me an hour to do a class. It took me longer than that to do Logs!

Although Len was able to implement what he considered alternative assessments in the same world as his colleagues, he ultimately felt several factors could be addressed so that a majority of teachers wishing to use more meaningful forms of assessment could do so. Factors Len felt would help teachers do a better job with assessment included: 1) a daily school schedule that was designed so that students could spend more time with one teacher and on more lengthy projects, 2) reduction of a terrific work load that already had teachers working to a high capacity, 3) providing teachers with their own classroom so that students could have longer-term projects going and/or more challenging assessments could be designed, 4) provide some time for sharing, trying, reflecting, and adapting, and 5) reducing class size to under 22 so that more contact time could be developed between the teacher and student. Len felt that if the educational system would address all, or part of these factors, some may act in concert to help teachers begin to use alternative assessments as he had: more now than in the past.

Plausible Implications for Science Teacher Educators

> "When teachers act in the classroom, they do what makes sense to them in their circumstances"
>
> K. Tobin (1990)

What might this all mean to science educators? Surely, findings from this case can only be used for the participants from this case. There was never any intention to generalize findings to any other situation, yet, many problems mentioned by Len and his colleagues are faced by other teachers. Some of the problems encountered by Len do have the potential to be addressed in part by science educators. Some plausible actions follow that science educators may wish to consider if there is indeed an interest in getting more meaningful science assessments into the classrooms.

Clearly, most science educators wish students to be involved in rich, scientific investigations that have them often using hands-on manipulatives, which aid them in answering their own questions. Likewise, rich assessments of students would include unstructured tasks (Wiggins, 1993 c), portfolios (Collins, 1992) or other performance assessments (Boycoff Baron, 1991). While this may be the ideal, Len discussed multiple factors which would impact the successful implementation of a consistent menu of rich assessments including: class size, student attitudes, available materials, and time, to name a few.

Alternatives to traditional tests might indeed provide the teacher and the student with higher levels of understanding in both process skills and content. However, the total package of variables that Len suggested which might lead to the ultimate in a successful implementation of rich assessments could easily be argued as not currently existing in most schools. In Len's case he was "doing the best he could" for the situation he was presented with and the level of understanding he currently held for assessment.

It seems that two key factors determined Len's perceived level of success in using alternative assessments. The first was his willingness to take a risk. The second was that he was shown or modeled an example, permitting him to "give it a try" in his classroom. For him, these models occurred at workshops or conferences. Providing pre-service teachers of science, models of alternative assessments which show natural links to grading and time management seems to be a logical way of promoting, if not at least reinforcing their later use. Alternative assessment examples should be research-based and pre-service teachers should be given ample time to practice using them so they begin their profession with an understanding about what meaningful assessments look like and how they are used.

In addition, the assessment strategies modeled in a pre-service program should demonstrate how assessment and instruction are inseparable when real learning is the goal. If assessment strategies in preservice programs model meaningful assessments and rise above multiple choice questions, there may be a greater chance they will be used when teachers begin their careers.

Since grades are still a definite issue in schools and valued above all else by students, parents, and administration, pre-service teachers may need shown methods for obtaining scores for any type of alternative assessment. Modeling rubric use and adding student-generated criteria in a science methods class may provide the examples necessary for these future teachers to implement rubrics with their own students. These rubrics would demonstrate a tool that bases student effort and skills against a pre-established set of criteria rather than a comparison between students.

Attending and presenting at science teacher conferences surely had an impact on Len's use of alternative assessments. First, attending conferences provided him support in "knowing he was doing the right thing," and presenting his "wares" to "packed rooms," filled with biology teachers eager to learn "about what he was doing," gave him the collegial support (albeit outside his school) to continue. It could be logically argued then, that attending and presenting at conferences contributes to keeping this teacher active and growing. Providing information to pre-service science teachers regarding upcoming conferences and strongly promoting and encouraging their attendance may well contribute to student confidence level and understanding regarding the use of alternative assessments.

Len's story as told by this researchers is by no means conclusive and cannot be directly compared to other science teachers. However, Len continues to this day to try new assessments and adapts proven methods to his new teaching scenarios. Len admitted that even after 30 years he was still learning. The most he could offer this researcher was that he was deeply concerned about his teaching and engaging his students. Len was simply doing the best he could for his situation. This researcher would agree.

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PERFORMANCE ASSESSMENT WITH PRESERVICE ELEMENTARY TEACHERS: IS IT WORTH THE EFFORT?

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Introduction

Performance tasks in science education have continued to gain credibility as an appropriate strategy for assessing students' science conceptual understandings and use of process skills (e.g., National Science Education Standards, 1996; Hein & Price, 1994). Lehman (1994) has also recommended performance tasks for assessing preservice teachers' ability to investigate science phenomena and use scientific equipment. Yet, an underlying goal of an elementary science methods course is to help preservice teachers learn to *teach science as inquiry* and develop something akin to "pedagogical content knowledge" (after Shulman). A central question for teacher educators becomes how to assess (in alternative ways to paper and pencil tasks) the ability of elementary preservice teaches to develop science inquiry experiences for young learners.

The purpose of this study was to document the implementation of a pedagogically-oriented performance assessment component within two elementary science methods courses spanning two semesters. *Phase I* denotes the first semester of the study while *Phase II* refers to the second semester. Assessment rubric notes, student feedback forms, and instructor field notes made up the data for the study. The focus of the performance assessment was on the preservice teachers' pedagogical thinking about science inquiry rather than their science background knowledge or their ability to conduct a scientific experiment. Phase II of the study reflected several revisions from the original assessment experience and is elaborated in the paper.

Phase I

Fifty-six elementary education majors from two sections of a science methods course participated in the performance assessment near the end of the semester long course during the spring semester, 1996. The performance task description, science topic, and scoring rubric (see Table 1) were given to the preservice teachers ahead of time for their review. Working with an assigned partner, they were asked to perform the following task: Show and discuss how the topic of "Sound" could be taught as inquiry using the everyday materials provided.

The teachers were given five minutes to collect their thoughts and fifteen minutes to articulate their pedagogical ideas. Each of the two instructors administered the assessment using the same science topic, format, and scoring rubric. The role of the instructors was to facilitate a discussion about the topic and to guide the teachers through the various categories of the assessment.

Table 1
Performance Assessment Task and Scoring Rubric

You will be given some everyday materials with which to conceptualize and discuss several science inquiry opportunities with learners. The topic will be the study of **SOUND**. Key concepts: sounds are produced by vibrations; more mass, the slower the vibration, lower the pitch; higher frequency the vibration the higher the pitch; the loudness (amplitude) or pitch (frequency) of sounds can be changed. Sound waves can travel through gases, liquids (faster), and solids (fastest). Assessment session: 20 minutes.

Points			
1	Open-ended questions to invite inquiry	2 open-ended questions 1 " "	= 1 point = .5 point
4	Exploration embedded in activity: teacher roles and student roles described	4 aspects of exploration 3 " " 2 " " 1 " "	= 4 points = 3 points = 2 points = 1 point
2	Application/Connection to real world	Activity-based Discussion-based	= 2 points = 1 point

1 Integration with two subjects	2 meaningful integrations = 1 point 1 meaningful integration = .5 point
2 Assessment	2 assessments with reasoning = 2 points 1 assessment with reasoning = 1 point

The scoring rubric was used as a template for the instructors to write preservice teacher responses, their own comments, and score the different categories. Copies of these notes and scores were shared with the teachers after the assessment. Teachers were also asked to anonymously evaluate the performance assessment in terms of the following: 1) value of the experience; 2) interaction with the instructor; 3) their own performance on the assessment; and 4) recommendations for future assessment practices.

Phase I Findings

Preservice Teacher Performance

Overall, the teachers performed very successfully in articulating their views about teaching science as inquiry and covering all the categories listed in the rubric. Although the topic (sound) and rubric were known ahead of time, the preservice teachers did not see the materials to be used until the moment of the assessment and were challenged intellectually to use the available materials as props to demonstrate their thinking in a coherent and meaningful way.

Preservice Teacher Perspective

Practical Value

The teachers believed that the performance assessment held a practical value for them in that they were demonstrating what they had learned and were utilizing common everyday materials to create inquiry. This is exemplified by these remarks: "I was able to apply abstract learning in a concrete way." "It tied together everything we've discussed and focused on this semester." "It let me verbalize my thoughts and feelings about how to use materials in my classroom."

Conversational Interaction with Instructor

The teachers also felt the conversational interaction with the instructor produced a comfortable, yet serious environment for the assessment. "It was like having a normal conversation. We were able to show what we learned without having to worry." "Liked how the teacher gave chance to explain thoughts yet continued to probe on things he wanted more elaborated." "We were asked probing questions that made us analyze our thinking."

Time Constraint

The participants often noted that too little time was allowed for the assessment. "Allow more time to complete the process." "Maybe allow a few more minutes for preparation. Time became a factor and I did feel a little rushed."

Topic Anxiety

The topic of "sound" used in the assessment was not familiar to many students and was not a topic covered in the course. This contributed to anxiety among many of the students. "Have choices on what to be assessed on. I didn't feel very comfortable with sound because we didn't even cover it in class." "Pick an idea or experiment that we have gone over in class. For example instead of sound, we could've had magnetism because we did something with that in class." "Give students more background on the subject." "I felt a little anxious beforehand because we were being assessed on sound--something we had not studied at all as a team during the semester. I thought this was strange because we have been taught to assess on what the students know."

Beneficial Experience

There was a general consensus among the participants that they were pleased with their performance and felt they did well. It was also felt that this type of assessment should be continued. "It is a helpful addition to building students' confidence in constructivist teaching." "This type of assessment is much better than a final. You actually get to put your knowledge and hands on activity to work." "Do more of this throughout the whole semester, not just at the end. This type of activity makes you think hard and be creative and I think that's a valuable assessment for constructivist science."

Instructor Perspective

The assessment was viewed as a very positive experience for both instructors of the science methods course. It was felt that this type of assessment reflected their students' understanding of the inquiry-based approach to teaching science that had been modeled by the instructors throughout the semester. The assessment also provided the students with an opportunity to pull together the pedagogical content knowledge that had been presented throughout the course and apply it to a new situation. "I liked the insight I gained about how inquiry is built as I listened to the students do their thinking aloud and to observe them using their prior knowledge to make connections to the new materials throughout the process." The instructors both viewed their role in the assessment process as facilitators rather than members of an inquisition. One instructor reflected that his role as facilitator was challenging on the point of always being consistent in the amount or type of prompts given during the assessment. Such inconsistency was noted as a concern for future practice. Both instructors stressed that modeling both an assessment practice and the teacher's role in that assessment to preservice teachers were critical aspects underlying the performance task.

Phase I Conclusions

Implementing a pedagogically-oriented performance assessment experience was found to be a rewarding experience for preservice teachers and instructors alike. Preservice teachers had the opportunity to articulate and demonstrate their thinking about teaching science as inquiry in a performance setting. Instructors were afforded an additional assessment strategy for evaluating their students and gained insights into the effectiveness of their own teaching through the students' performances. Notably, the sharing of the rubric content and science topic ahead of time with the teachers was a critical factor in reducing stress associated with the performance task and helping teachers focus on pedagogical matters.

Phase II

The revisions during this phase of the study were influenced by the feedback from the preservice teachers (particularly the time constraint and topic anxiety) during Phase I and the views on performance assessment of Wiggins (1993). According to Wiggins, ". . . because the student is the primary client of all assessments, assessment should be designed to improve performance, not just monitor it" (p. 6, emphasis in original). Therefore, several fundamental changes were made during Phase II: Students were free to pick their own topic, students met with the instructor individually, and the scoring rubric was replaced by a revised rubric checklist.

Sixty elementary education majors from two sections of a science methods course participated in the performance assessment near the end of the semester long course during the fall semester, 1996. The assignment description and revised rubric outline (see Table 2) were provided to the preservice teachers about two weeks before the performance assessment.

Table 2
Performance Assessment Description and Rubric

We will have the opportunity to **converse** about teaching science as inquiry to young learners. The choice of topic is up to you. Please bring along a few props to add a concreteness to the conversation. The purpose of the assessment in to allow you to articulate your views about the **pedagogical considerations** underlying inquiry-oriented science teaching. The topic you select will be the vehicle for elaborating these views. **Reasons and evidence** that back up your thoughts and ideas strengthen the credence of your views. Each session will last 20 minutes.

	Engagement	Questioning strategies and examples, students' prior knowledge, focusing, orientation.
	Conceptual Development	Description of how the learner is engaged in investigation; How concepts are introduced and developed; Flexibility in lesson direction (student interests/curriculum demands).
	Elaboration	Application/Connection to real world; Integration with other subject areas.
	Assessment of Student Understanding	Strategies used to assess learner understandings; types of records/products used.
	Inquiry: Your Journey in Progress	Goals, challenges, concerns, dilemmas about teaching science as inquiry.

The scored weight of the assessment was the same as Phase I (10% of the final grade) but the scoring was not broken down into specific points. The students were informed that they were expected to address each issue on the rubric and if they did, they would receive full credit. Particular emphasis was given the "Journey in Progress" section of the assessment in order to encourage the students to reflect honestly on their progress toward inquiry teaching and see their growth more as a process rather than a fixed destination.

Before the performance assessment, the students completed an "inquiry notes" form that contained the same categories as the rubric checklist. This afforded the instructors to be more actively involved with the assessment conversation rather than writing down the students' responses and ideas.

Phase II Findings

Preservice Teacher Perspective

Opportunity to Reflect

"I was able to reflect on everything I've learned this semester and incorporate my beliefs and practices into that." "I discovered that I am a learner." "I was able to reflect on how I prepared my lesson. I was able to look at myself as a teacher and evaluate what I wanted students to understand and grasp in my lesson." "It makes you think how you would assess students in hands on activities."

Articulate and Clarify Thoughts

"I felt I was able to share my ideas and go into depth more about what I wished I could have done with my students." "Made me think about different ways to experiment with this activity" "I saw things in a different way, one that made more sense than my original view."

Encouraged Discussion and Sharing

"Talking through the topic helped me to understand the topic more clearly and it was good to hear feedback on my ideas." "Very low stress but helpful." "Discussion on ideas, positive feedback, one on one discussion and helpful insights. This was valuable to the learning process." "Good experience to talk one on one with the professor."

Helpful Feedback

"It allowed me to feel more confidence in my abilities." "I feel I'm on the right track."

"Encouraged me and challenged me. Gave me confidence to continue pursing the beliefs I have developed over the semester." "It gave me an idea of where I was at now and where I can go with myself."

Affirmed Confidence to Teach Science

"By discussing the inquiry process, I feel confident in myself that I can and will teach science in a constructivist approach." "I was able to see growth in my abilities to teach science." "I now know that I am capable of teaching science and have the foundation to do just that." "It gave me confidence that I really can do it, be a teacher, and not all my ideas are wrong."

Instructor Perspective

The one-on-one conversation format between a student and an instructor provided a relaxed atmosphere that seemed to invite a spontaneous sharing of ideas. There was an openness, a sense that both parties were learners and that all ideas were valuable. The assessment format also provided the opportunity for the instructors to affirm the students as teachers and how they might continue to move ahead. Lastly, the assessment informed the instructors' practice and offered insights into the pedagogical ideas and educational needs of the students.

Phase II Conclusions

The revised performance assessment allowed the preservice teachers to discuss a familiar topic of their choice that they had implemented with elementary aged children. This revision helped reduce the overall anxiety of the preservice teachers and helped them prepare successfully for the assessment. Their confidence and depth of discussion were greater in comparison to the Phase I participants. The added section on the rubric addressing their journey created a positive format for honestly addressing issues, concerns, and dilemmas commonly encountered by teachers and teacher educators.

Discussion

Performance assessment formats that encourage an exchange of ideas provide numerous benefits to preservice teachers and teacher educators alike. Preservice teachers are given helpful feedback in terms of their thoughts and actions regarding the teaching of science and inquiry. Teacher educators are provided feedback from their students that can inform their classroom practice. In order to move toward a performance assessment experience as envisioned by educators such as Wiggins, science teacher educators need to critically examine the forms of assessment currently practiced and seriously consider the student benefit over teacher convenience. Yet, several issues remain: Does removing a scoring system undermine the validity of such assessments? If levels of understanding are a part of the assessment, how are such levels measured? How can teacher educators build rapport with their students without sacrificing rigor on the part of the preservice teachers' expectations and effort? Continued research is needed to address these important issues.

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ORGANIZATION, IMPLEMENTATION, AND RESULTS OF AN EISENHOWER SYSTEMIC ELEMENTARY SCIENCE REFORM PROJECT

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Overview

Most teachers and school administrators are familiar with Eisenhower funds that are used by schools to support science and mathematics inservice. These funds are available to school districts from state departments of education, usually on a per-pupil allocation. Another category of Eisenhower funds are available from the U.S. Department of Education through state agencies that govern higher education. Eisenhower grants are awarded on a competitive basis to colleges and universities across the United States. The objectives of Eisenhower Programs include (1) improve the science and mathematics skills of teachers; (2) improve the understanding of science and mathematics by students; (3) increase access of students to instruction in science and mathematics; and (4) promote cooperative programs among institutions of higher education, local education agencies, private industry, and nonprofit organizations; (5) attract female and minority students to the natural sciences, because they have traditionally shown a lesser level of interest in the natural sciences or in pursuing science and mathematics careers.

The main purpose of this paper is to provide background information and describe a collaborative Eisenhower project that is bringing local systemic reform in elementary science to the Northwest Local School District (NLSD) of Cincinnati. This project is currently in the 16th of 19 months.

Background

Over a decade ago, a sense of public urgency was aroused by the realization that enormous numbers of US citizens are scientifically and technologically illiterate (Johnston & Aldridge, 1984). Science teaching as it is usually practiced, does not develop students' scientific literacy, higher reasoning ability, and the application skills necessary to benefit society (Cole, et al., 1991).

Most elementary teachers do not like science and feel unprepared to do an adequate job of teaching science (Tilgner, 1990).

Numerous studies have shown that an investigative and activity oriented approach to elementary science promotes intellectual development and the development of scientific literacy and "basic skills" such as reading, writing, and mathematics (Kotar, 1988; Kyle, 1988; Lloyd & Contreras, 1987). Students in hands-on elementary science programs become actively involved in direct experiences with the processes of science as they observe, compare, classify, measure, collect and interpret data, organize information, and draw inferences or conclusions. Under the supervision of a confident and well-prepared teacher, students attain a sound comprehension of science concepts and processes and develop positive attitudes toward science. However, many teachers are unsure of the purpose of hands-on activities or how to make them genuine learning experiences.

Needs Assessments

A needs assessment was conducted in the NLSD. Those responding were identified by their principals as leaders in elementary science instruction. The results indicated a high level of interest in "hands-on minds-on" science and other features proposed for the project. A summary of the needs assessment may be found in Appendix A. Additionally, in a separate needs assessment conducted by NLSD during 1994-95, two-thirds of those responding indicated a need for more assistance with physical sciences, one-third indicated a need for more assistance with biological sciences, and 41% indicated a need for more information regarding alternative assessment. During the spring, 1995, two science teachers were identified at each elementary building (one primary and one intermediate). They were interviewed and asked to describe the issues related to science instruction at the elementary level. These teachers overwhelmingly supported a hands-on approach to teaching science. They identified the lack of materials and lack of sufficient hands-on training as impediments to science instruction at the elementary level. These indicators *and* previous experience with hands-on inservice workshops guided the development of the project; its objectives, design, content and methods; selection of teacher participants; and means of project evaluation.

Project Objectives

The objectives of this project are enumerated below.

1. Contribute to the development of a new grade K-5 elementary science curriculum emphasizing inquiry-based hands-on science; its integration with other subjects; and appropriate alternative assessment.
2. Improve competence of 72 NLSD and three administrators in science concepts, attitudes, processes and inquiry.
3. Develop increased confidence and eagerness of participants to teach science by inquiry emphasizing science concepts, processes, and attitudes.
4. Establish regular inservice activities and activity-sharing by participants and project staff in the fall, 1996.
5. Contribute to a growing supportive network of excellent elementary science teachers in southwest Ohio.
6. Develop locations for meaningful elementary science field experiences and student teaching placements for elementary education majors.

Beneficial Outcomes

Program participants receive: (1) a three-week activity oriented workshop including hands-on inquiry activities and assistance in overcoming inherent difficulties teaching hands-on science (summer, 1996); (2) three day-long follow-up Saturday seminars during the fall, 1996 semester, to share ideas and successes and find moral support for implementation; (3) two classroom consulting visits by the project director or science coordinator during the 1996-97 school year; (4) eight semester hours of graduate credit with all tuition and fees waived; (5) workshop instructional materials; and (6) a stipend of $360 ($20/day for 18 days). Participating teachers agree to: (1) actively participate in all workshops and seminar sessions; (2) teach science on a regular basis, using a process-oriented, inquiry approach; and (3) work individually or with other participants to conduct at least two prescribed inservice activities. Participating schools receive: confident elementary teachers eager to teach science-by-inquiry and integrate science with other subjects; alternative assessment procedures; maximum student achievement in science and on science proficiency exams; major inservice activities; model classrooms for elementary science instruction; and administrators who are up-to-date regarding elementary science programs.

Prior to student teaching, extensive in-school field experiences are required for preservice elementary education students in Ohio. The implementation of this proposal would assure effective field experiences and student teaching placements for many years for teacher education students who complete field work in the NLSD. Miami University (MU) will also benefit from a cadre of excellent K-5 science teachers for ongoing inservice activities of the MU Center for Mathematics and Science Education.

Activities

District activities related to the project might be summarized as follows:

1. Organizing and limiting science topics to be taught at each grade level;
2. Developing a curriculum and reviewing science materials;
3. Selecting science materials to be piloted;
4. Adopting and purchasing science materials;
5. Encouraging teacher applications to become project participants;
6. Sponsoring inservice activities for teachers who did not become participants.

During 1995-96, the NLSD conducted an elementary science curriculum review and development process resulting in the adoption of a non-text inquiry-based program. They attempted to adopt a curriculum that would include all elements designated by the Ohio model science curriculum for effective elementary science teaching including inquiry experiences (Ohio Department of Education, 1994). Six major programs were considered including Science and Technology for Children (STC) published by Carolina Biological; Full Option Science System (FOSS) published by Britannica; SCIS 3 and other Delta Science Modules distributed by Delta

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Education; Science Place published by Scholastic, Inc.; AIMS; and GEMS. The AIMS and GEMS materials were reviewed and found to be important as potential supplements to the units published by the other four companies listed above. None of the four major publishing companies offers a single hands-on program that would cover all of the units that were determined necessary for the NLSD grades K-5. Consequently, the adopted materials would not be exclusively from any one company. Materials eventually adopted included Seven units from STC, four from FOSS, 10 from Science Place, one from SCIS-3, and one from Delta Science.

The project includes 72 teachers and 3 administrators who attended a three-week summer workshop organized into three separate grade level groups, K-1, 2-3, and 4-5, with an average of 25 participants in each group. Each grade level workshop included 15 days of formal instruction, laboratory and field experiences. Formal instruction (generally 9:00 a.m. to 12:00) covered physical, biological, and earth science concepts appropriate for the district's new science curriculum. During laboratory time (12:30 to 3:30 p.m.), participants worked in small groups with hands-on materials and learning centers to provide them with grade level activities that supported the adopted program. Laboratory time allowed teachers to carry out individual projects and undertake long-term activities and observations that would be used in their classrooms. Project workshops supported the revised curriculum and emphasized hands-on inquiry activities, selected science content, the integration of science with other subjects, and alternative hands-on assessment. Learning by inquiry included activities emphasizing a search for solutions rather than answers revealed directly by the teacher. Particular emphasis was placed on the processes of investigations. Teachers gained an operational knowledge of integrating investigative activities with mathematics, language arts, fiction and non-fiction trade books.

Summer workshops were led by classroom teacher-leaders who worked with the same group for the entire three weeks and for the follow-up Saturday seminars. The teacher-leaders have had extensive success using investigative, hands-on approaches to science instruction and have previous experience instructing hands-on science projects for MU. They provided stability and methodology, working with teachers of their own grade level expertise. One of the professors is a botany professor providing expertise in biological science. The other is a professor of science education providing expertise in the physical sciences and science education. The two professors rotated from one grade level group to another, spending time with each as their subject matter area is scheduled.

A workshop follow-up includes inservice activities and classroom visits by the director and curriculum coordinator to assure the appropriate implementation of workshop activities and methods. Participants are observed teaching hands-on science in their classrooms, and they receive oral and written feedback. Observers offer suggestions on teaching methods, science content, materials management, learning centers, and displays. Three six-hour follow-up seminars are conducted during the 1996 fall semester by the project staff. These include instruction in science content and methodology, sharing ideas and experiences, and planning and conducting inservice activities. Workshops, seminars, inservice activities, and classroom observations are integrated for continuity.

Inservice activities enable participants to share ideas and experiences with teachers who did not participate in the project by presenting at least two inservice programs each. Possible formats include regularly assisting another teacher in the building for one full semester; grade-level inservice for building or district; and inservice for buildings other than those of the participants. The district hosted a half-day science inservice for K-5 teachers, Friday, Nov. 1, 1996. All K-5 teachers in the district and in selected Archdiocese schools were released to attend.

Participant Selection

Participants in this project were selected on the basis of demonstrated teaching competence and commitment to project objectives. Each applicant's principal must confirm instructional competence and assure that the teachers are provided with the necessary hands-on materials. Selection criteria included appropriate certification, grade level, history of honors, service to district committees, and demonstrated efforts for self-improvement.

Teachers without previous experience with hands-on workshop opportunities but are eager to employ this approach in their classrooms were considered prime candidates. A special emphasis was placed on recruiting teachers from underrepresented and underserved groups and on teachers in schools with higher poverty level enrollments. Applicants from the same school who applied as a team were also given extra consideration in order to establish cooperative teams of teachers and administrators. An attempt was made to balance grade level representation.

Each minority teacher in participating schools received a special personal invitation from the project director to apply, was encouraged to apply by school administrators, and was given extra consideration for selection. At least 10% of the participant positions were designated for minority groups. Minority participants were sought from Archdiocese schools outside of the target schools to assure this level of U/U participation.

Evaluation

Prior to the start of the workshops, participants were given a pretest to assess their level of comfort with teaching science, attitudes toward science and science teaching, and subject matter competence. Similar assessments were given at the end of the summer workshop and will be given again at the end of the final Saturday seminar. It was expected that participants would demonstrate significant cognitive and affective gains between the pre and posttest and maintain these gains as indicated on post-posttests. At the end of the first week of the summer workshop, participants completed anonymous formative evaluations of the workshop expressing opinions of each aspect of the workshop and suggestions for improvement. They provided an anonymous summative evaluations of the workshop at the end of the third week and will again at the end of the project. They were asked their opinions of the project; level of interest in continued use of hands-on science; level of enthusiasm for continued inservice work; and willingness to serve as a resource for pre-service elementary education majors. A random sample of participants are being interviewed by the evaluator for an in-depth qualitative evaluation. Throughout the project, all tests, and evaluations were developed, administered, and analyzed with the consultation of the project evaluator who was responsible for project research design and statistical analysis of data. Classroom observations confirm the level of effective implementation of workshop activities and philosophy. A written assessment of teaching effectiveness for each participant is being collected and analyzed.

Results of Cognitive and Affective Testing

The project includes pre, post, and post-posttesting of cognitive and affective factors, but post-posttests have yet to be administered. The results thus far are reported in this paper. The pretests were administered on the first day of the three-week summer workshop, and posttests were given on the last workshop day. Post-posttests will be taken by participants near the end of the current semester.

Cognitive Analysis

Knowledge of selected science concepts and science teaching practices were assessed using a 25 item multiple choice test prepared by the project Director and workshop instructors. Each item had five possible responses. Items included basic concepts from biology, physical science, environmental science, earth science, and science methodology.

Total cognitive test scores were determined for each of the three groups and for two periods. The means and standard deviations for each period are reported in Table 1. The dependent cognitive variable was analyzed using a two way repeated measures analysis of variance with grade grouping representing one factor (three levels K-1, 2-3, and 4-5) and time of testing representing the repeated measures factor (pre and post tests). Analysis results are reported in Table 2. There was no test-period-by-group interaction, so any difference indicated could be generalized to all three grade level groups. The F-ratio associated with grade grouping was barely significant (F=3.16, $p<.05$) because teachers at the 4-5 levels scored higher than teachers at the K-1 levels. The time of testing factor defined a significant F-ratio (F=88.64, $p<.05$), indicating that the two time periods differed significantly on the cognitive variable.

Table I

Cognitive Test Means-Repeated Measures

Group:	Count	Mean:	Std. Dev:
pretest K-1	24	.60	.13
posttest K-1	24	.70	.15
pretest 2-3	28	.66	.11
posttest 2-3	28	.75	.09
pretest 4-5	16	.72	.16
posttest 4-5	16	.78	.16

Table II

Cognitive Test, 1996 Two Factor ANOVA-Repeated Measures

Source:	df:	Sums of Squares:	Mean Square:	F-test	p value
Group	2	.19	.10	3.16	.05
Subject (Group)	65	1.99	.03		
Test Period	1	.25	.25	88.64	.0001
Test Period*Group	2	.01	.004	1.50	.23
Test Period*Subject (Group)	65	.18	.003		

Affective Analysis

Attitudes toward science and science teaching were assessed using a modified version of the "Scientific Attitude Inventory" (Moore, 1973). The original inventory consisted of 70 statements to which subjects are asked to respond on a four point Likert scale from "strongly agree" to "strongly disagree." For use with this project, the inventory was shortened to 27 items by eliminating some "duplicate" items and items statistically shown not to contribute to differentiation between test periods for this project. On the response scanner form "strongly agree" = 0 and "strongly disagree" = 3. For about half the items the preferred response was "strongly agree" (0). For the rest the preferred response was "strongly disagree" (3). For statistical analysis the numerical value of the responses was "reflected," so that all preferred responses were read as three. Within the 27 items on the attitude inventory, two main factors were identified. The first factor was identified as "attitude toward the *understanding and teaching* of science." Thirteen items could be identified with the first factor. The second factor was identified as "attitude toward the *philosophy* of science." Fourteen items were identified with the second factor. Analysis of each factor may be found below.

Analysis of Attitude toward the Understanding and Teaching of Science

Average attitude scores regarding the understanding and teaching of science were determined for each participant for pre-workshop and post-workshop periods. The means and standard deviations by period are reported in Table 3. Participants started with somewhat positive attitudes as may be noted by their mean pretest scores. The scores by period were analyzed with a two-way repeated measures analysis of variance as shown in Table 4. The significant period effect suggested significant differences over time (F=26.96, p<.05). There was no difference between grade level groups. There was no time-by-grade level interaction, so the difference could be generalized to all three groups.

Table III

Affective Analysis for Participants Attitude Toward the Understanding and Teaching of Science Means-Repeated Measures

Group:	Count	Mean:	Std. Dev:
pretest K-1	25	2.13	.36
posttest K-1	25	2.44	.22
pretest 2-3 s	28	2.23	.29
posttest 2-3	28	2.52	.24
pretest 4-5	17	2.18	.27
posttest 4-5	17	2.37	.29

Table IV

Affective Analysis for Participants Attitude Toward the Understanding and Teaching of Science Two Factor ANOVA-Repeated Measures

Source:	df:	Sums of Squares:	Mean Square:	F-test	p value
Group	2	.32	.16	2.17	.12
Subject (Group)	67	4.95	.07		
Test Period	1	2.30	2.30	26.96	.0001
Test Period*Group	2	.08	.04	.45	.64
Test Period*Subject (Group)	67	5.71	.09		

Analysis of Attitude toward the Philosophy of Science

Average attitude scores regarding the philosophy of science were determined for each participant for pre-workshop and post-workshop periods. The means and standard deviations by period are reported in Table 5. Participants started with somewhat positive attitudes as may be noted by their mean pretest scores. The scores by period were analyzed with a two-way repeated measures analysis of variance as shown in Table 6. The significant period effect suggested significant differences over time (F=18.38, p<.05). There was a small difference between grade level groups (F=3.29, p<.05) but no time-by-grade level interaction.

Table V

Affective Analysis for Participants Attitude toward the Philosophy of Science Means-Repeated Measures

Group:	Count	Mean:	Std. Dev:
pre score K-1	25	2.01	.29
post score K-1	25	2.22	.23
pre score 2-3	28	2.15	.29
post score 2-3	28	2.33	.21
pre score 4-6	17	2.17	.19
post score 4-6	17	2.30	.29

Table VI

Affective Analysis for Participants Attitude Toward the Philosophy of Science Two Factor ANOVA-Repeated Measures

Source:	df:	Sums of Squares:	Mean Square:	F-test	p value
Group	2	.47	.24	3.29	.044
Subject (Group)	67	4.80	.07		
Test Period	1	1.03	1.03	18.38	.0001
Test Period*Group	2	.04	.02	.34	.7130
Test Period*Subject (Group)	67	3.75	.06		

Summary

Testing appears to indicate that project objectives related to the improvement of science understanding and attitudes toward science are being met. Cognitive test scores for each group improved significantly from pretest to posttest. Affective testing indicate significant improvement of attitudes toward science, science teaching, and the philosophy of science. The design and implementation of this project appears to have contributed significantly to the cognitive gains of participants and to their attitudes toward science and science teaching, and the philosophy of science. Casual observation suggests that affective scores improve in a manner similar to the improvement of cognitive scores.

One significant casual observation has been that participants had much less difficulty adapting to the procedures and methods of hands-on science than to some basic generic teaching expectations. During summer workshops and academic year seminars, project faculty emphasized and regularly modeled how to get students involved at higher cognitive levels and how to use effective questioning skills. Still, many participants have difficulty demonstrating these skills in their own classrooms. In many cases it seems that participants have never mastered skills such as planning, introducing and concluding a lesson, and higher level questioning techniques.

Other objectives of the project seem to be meeting with success. Project Director visits to have provided a wide array of inservice activities within and outside the district. All have provided at least two inservice activities within the district. A few have submitted proposals for state and local conference presentations. A growing network is linking participants of this project with participants in other southwestern Ohio hands-on science projects. They have opportunities to share ideas and provide moral support through regional conferences and newsletters. At the very least, hands-on minds-on science has taken root in southwestern Ohio.

Eisenhower Funding for this and Similar projects

The major source of Eisenhower funds for all 50 states is the U.S. Department of Education. Federal funds are allocated to each state department of education and to each state board of regents. Funding for the project described herein includes $42,648 from the Ohio Board of Regents Eisenhower Program. Eisenhower funds are supporting teacher-leader salaries and participant stipends. Teachers are receiving eight semester hours of credit with fees waived by Miami University. Costsharing by Miami University includes $70,000 for staff salaries, travel, workshop materials, and office expenses. School districts' costsharing of $166,000 includes the cost of adopted hands-on science materials and in-kind support for administration and inservice sessions.

Funds from college and university Eisenhower Project are not available directly to schools or teachers. Any local education agency interested in participation in a viable project could approach a nearby college or university to determine if they would be interested in developing and participating in such an effort. It would be prudent to approach science or mathematics educators in departments of education, mathematics, or natural sciences. If a good match is made, another collaborative effort between higher education and one or more local education agencies funded by the Eisenhower Program may well be realized.

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Appendix A

Summary of Needs Assessment

Elementary Teacher Science Inservice Survey

Please rate each item based on your opinion of how valuable a contribution it might make to elementary science instruction as part of a major elementary science inservice project (circle the preferred response.)

(1=not at all..........5=very much)

		M	N
1. Science subject matter for elementary teachers	1 2 3 4 5	3.80	30
2. Science content of the adopted program	1 2 3 4 5	3.40	30
3. Teaching methods of the adopted science program	1 2 3 4 5	4.00	30
4. Activity oriented "hands-on minds-on" approach	1 2 3 4 5	4.90	30
5. Coordination with the state curriculum and proficiency exams	1 2 3 4 5	3.77	30
6. Feedback regarding your own science teaching	1 2 3 4 5	3.27	30
7. Please indicate the level of interest you would have in attending an inservice project as described above.	1 2 3 4 5	4.53	30

Appendix B

Adopted Elementary Science Topics

Gr		PHYSICAL		LIFE		EARTH
K	1	Color, Shapes, Sizes	1	Five Senses	1	Seasons
	2	Water (Sink and Float)	2	Animal Characteristics	2	Day/Night
1	1	Light/Shadow	1	Animal Habitats	1	Sun/Moon/Earth
	2	Balance (Weight)	2	Plant Characteristics	2	Weather
2	1	Magnetism	1	Dinosaurs/Fossils	1	Rocks & Minerals
	2	Sound	2	Ecological Communities	2	Oceans
					3	Water Cycle
3	1	Simple Machines	1	Vertebrates (including classification)	1	Solar System
	2	Force and Motion			2	Weather/Climate/Atmosphere
4	1	Matter	1	Ecosystems Environmental Issues	1	Geological Forces
	2	Physical Changes				
	3	Properties				
5	1	Energy	1	Invertebrates (including classification	1	Astronomy (including cycles of sun, moon, earth)
	2	Chemistry			2	Rocks/Minerals Soil

USING EXPERT OPINION TO GUIDE ITEM SELECTION FOR AN INSTRUMENT TO MEASURE 5TH-GRADE STUDENTS' UNDERSTANDING OF THE NATURE OF SCIENTIFIC KNOWLEDGE

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Abstract

This paper describes the methodology and presents the findings of a study done to select items for inclusion in an instrument to measure 5th-grade students' understanding of the nature of scientific knowledge. One hundred sixteen scientists and 38 science educators responded to a Likert survey in which they were asked to rate the: (a) accuracy and importance of eight propositional statements that form the model of scientific knowledge on which the instrument is based; and (b) the truth or falsity of 64 potential item statements. The data suggest that: (a) the eight propositions are all accurate and important statements about the nature of scientific knowledge; and (b) that there is consensus as to the truth or falsity of 45 item statements.

The data were also examined for evidence of differences in the perception of the nature of scientific knowledge among science educators and (a) scientists, (b) scientists grouped by working environment—agency, industry, or university; and (c) scientists grouped by discipline. The analysis revealed some potentially interesting, statistically significant, between-groups differences. However, these differences, as might be expected given the simplicity of the model of scientific knowledge used, were modest.

Scientific Literacy

A number of recent efforts have sought to redefine and create new standards for science education. Three of the most prominent were the National Science Education Standards from the National Research Council (NRC), Project 2061 from the American Association for the Advancement of Science (AAAS), and Scope, Sequence, and Coordination of Secondary School Science from the National Science Teachers Association (NSTA). Common to these reform efforts was the identification of the need to: (a) enhance the scientific literacy of all Americans as the goal of K-12 science education; and (b) promote inquiry based, hands-on teaching of science as a

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This paper was presented at the January 1997 AETS conference in Cincinnati, OH. under the title Content validation of an instrument to measure 5th-grade students' understanding of the nature of scientific knowledge.

crucial pathway to scientific literacy (AAAS, 1989; NRC, 1996; National Science Board, 1983).

Over the years, the NRC (1988, 1996), the NSTA (1992), the AAAS (1993), and a host of individuals have offered definitions of the term *scientific literacy* and/or discussed what characterizes a *scientifically literate* person. Analysis of the many definitions reveals five dominant, recurring attributes of the scientifically literate individual. These attributes are: (a) a realistic understanding of the nature of scientific knowledge and the scientific process; (b) possession of a range of skills identified with the process of scientific inquiry; (c) familiarity with a knowledge base that includes the fundamental concepts and theories of science; (d) an understanding of the inter-relationships between science, technology, and society; and (e) the ability to apply the preceding four attributes to one's personal, civic, and work lives.

The Nature of Scientific Knowledge

Citing references as early as 1959, Kimball (1968) noted that "one of the most commonly stated objectives for science education is the attainment of an understanding of the nature of science" (p. 110). In 1982, the NSTA emphasized the development of students' understanding of the nature of the scientific process and scientific knowledge as crucial tasks for science educators. Lederman and O'Malley (1990) reported that understanding the nature of science had been a "perennial objective" (p. 225) of science education for thirty years. Meichtry (1992) identified understanding the nature of science as a critical component of scientific literacy and reported in 1993 that the literature had been consistent in identifying an understanding of the nature of science and scientific knowledge as key components of scientific literacy. In 1995, Shamos stated that understanding the nature of scientific knowledge is a vital part of scientific literacy, a position reiterated by the NRC in 1996.

Nature of Science versus Nature of Scientific Knowledge

Meichtry (1993) reported that the nature of science and the nature of scientific knowledge have been used interchangeably in the literature. Meichtry warned, however, that there are distinctions "that merit discussion" (p. 430). According to Meichtry, the nature of science is a broad concept that includes the nature of scientific knowledge, the scientific enterprise, and scientists themselves. In the current study, it is argued that to understand the nature of scientific knowledge one must understand the scientific process and the scientific enterprise. Meichtry said that the "definitions for both the nature of science and scientific knowledge presented in the literature are multifaceted" (p. 432) and cautioned that there is no "standardized definition" (p. 432) for either term.

Importance

Cotham and Smith (1981) offered an explanation of why it is important to understand the nature of science. They stated that for people who do not understand the tentative and developmental nature of scientific knowledge, cynicism is a frequent and reasonable reaction when faced with new scientific observations and/or theories that contradict accepted positions. Duschl (1990) warned that science may be seen as irrational by those who do not understand the nature of scientific knowledge and who are, therefore, unable to accept reformulations of scientific ideas. The AAAS (1993) and the NRC (1996) said that understanding the nature of scientific knowledge has a direct impact on individuals' ability to make informed choices on the environment, health, and other science related issues that effect their civic, political, and personal lives.

Shamos (1995) argued that the understanding of the nature of scientific knowledge is important in itself, and vital if students are to retain scientific concepts taught as part of the content dimension of scientific literacy. Shamos, in cautioning against expecting the average citizen to be able to participate in a meaningful way in the discussion of science related issues, argued that society should expect individuals to be able to assess, and then accept or reject the opinions and/or positions of experts. Shamos did not explicitly make the point, but it is reasonable to assume that an understanding of the nature of scientific knowledge is necessary if one is to evaluate the statements of experts on science related issues.

Definition

In a 1997 study, Alters turned to philosophers of science as the highest authority on the nature of science. Based on his survey of a random sample of members of the Philosophy of Science Association who held the rank of assistant professor or higher at American universities, Alters reported that the philosophers varied on their views of the nature of science. This study illustrates that, even among experts, there is disagreement about the true nature of science.

Numerous studies have documented differing perceptions of the nature of science among philosophers of science, scientists, science education professors, and K-12 science teachers (Atler, 1997; Cleminson, 1990; Pomeroy, 1993). In pursuing the task of developing an instrument to measure 5th-graders' understanding of the nature of science, the title to Alter's 1997 paper is cogent: "Whose nature of science?" Atler reported that those he considered the most expert, the philosophers of science, differed with the tenets on the nature of scientific knowledge advanced by the AAAS, the NRC, and the NSTA in defining the current science reform movement. Despite Atler's implied criticism of their view of the nature of science, the AAAS' Science for all Americans (SFA) and Benchmarks for Scientific Literacy (BSL), and the NRC's National Science Education Standards (NSES) are the seminal documents of the science reform movement. In developing an instrument for use with 5th-graders, the decision was made to examine what these publications say about the nature of science.

Rutherford and Ahlgren (1990) stated that SFA "represents the informed thinking of the scientific community as nearly as such a thing can be ascertained" (p. xv). SFA begins its discussion of the nature of science with the statement that "Scientists share certain basic beliefs and attitudes about what they do and how they view their work" (p. 1). Throughout the discussion of the nature of science, SFA refers to what scientists do and what scientists believe.

The preface to BSL stated that "an unprecedented number of elementary-, middle-, and high school teachers, school administrators, scientists, mathematicians, engineers, historians, and learning specialists participated in the development of Benchmarks and its nationwide critique" (p. vii). BSL further claimed to be based on the "solid findings" (p. xiii) of the research on students' understanding and learning. In discussing the nature of science, BSL consistently refers to the practice and beliefs of scientists.

The NSES stated that "teachers; science supervisors; curriculum developers; publishers; those who work at museums, zoos and science centers; science educators; scientists and engineers across the nation; school board members; parents; members of business and industry; and legislators and other public officials...were involved in the development of the National Science Education Standards" (p. ix). The NSES, like SFA and BSL, discuss the nature of science in terms of the practice and beliefs of scientists.

Note is made that the literature includes criticism of scientists' qualifications to define the nature of scientific knowledge. Pitt (1990) and Shapiro (1994) are among those who have written that working scientists have incomplete understanding of the nature of science. Despite this criticism, given the unanimous operational definition of the nature of science in terms of the practice and beliefs of scientists in the defining documents of the science reform movement, the decision was made to turn to scientists in establishing the content validity of the instrument to measure 5th-graders' understanding of the nature of scientific knowledge. To accommodate the criticism of scientists as experts on the nature of science, university based science educators were included in the content validation sample.

Student Understanding

Meichtry (1993) reported Rubba's 1977 disclosure that large numbers of students do not understand the nature of scientific knowledge. This finding echoed results published by Cooley and Klopfer (1963), Kimball (1968), Korth (1969), and Aikenhead (1973), in addition to Meichtry's (1993) own conclusion that there is widespread misunderstanding of the nature of science by students at all levels.

Models

In 1968, Kimball proposed a model of scientific knowledge based on eight declarations. These declarations were that science: (a) is driven by curiosity; (b) is dynamic and ongoing; (c) strives for comprehensiveness and simplicity; (d) has no single methodology; (e) is a system of values rather than an armamentarium of techniques; (f) is based on the assumption that the physical universe can, in principle at least, be described and explained; (g) is open to scrutiny; and (h) is tentative and uncertain. Showalter (1974) identified nine attributes of scientific knowledge. Scientific knowledge, he said, is: (a) tentative; (b) public; (c) replicative; (d) probabilistic; (e) humanistic; (f) historic; (g) unique; (h) holistic; and (i) empirical. Rubba and Andersen (1978) consolidated Showalter's nine factors into a six factor model, stating that scientific knowledge is: (a) amoral; (b) creative; (c) developmental; (d) parsimonious; (e) testable; and (f) unified. In 1981, Cotham and Smith characterized scientific knowledge as tentative and revisionary. Lederman and O'Malley (1990) combined the definitions of Rubba and Andersen and Cotham and Smith. They replaced Rubba and Andersen's developmental proposition with Cotham and Smith's idea that scientific knowledge is tentative and revisionary, and retained Rubba and Andersen's other five propositions. In revising Rubba and Andersen's (1978) measure of understanding of the nature of scientific knowledge, Meichtry operationalized the definition in 1992 by retaining the propositions that scientific knowledge is: (a) creative; (b) developmental; (c) testable; and (e) unified. Meichtry dropped the propositions that scientific knowledge is amoral and parsimonious, and made a limited number of changes to the item statements used. Meichtry did not, however, provide an account of the validation of the modified model for use with middle school students.

Validity

Validity refers to "the appropriateness, meaningfulness, and usefulness of the specific inferences made from test scores" (p.9, American Educational Research Association, American Psychological Association, National Council on Measurement in Education, (AERA/APA/NCME) 1985). That is, the inferences made from test results, not the test itself, are subject to validation.

Three categories of validity evidence have traditionally been considered. These categories are known as: (a) content validity; (b) criterion validity; and (c) construct validity. More recently, consequential validity has emerged as a new category.

Content Validity

Content validity refers to the extent to which the particular items included in a given test are "representative of some defined universe or domain of content" (p.10, AERA/APA/NCME, 1985). Evidence supporting the content validity of inference based on the results of a given test often rely on the judgment of experts as to whether the test items fit the construct being tested. The AERA/APA/NCME advises that evidence of content related validity should be a central concern during test development and that "expert professional judgment should play an integral part in developing the definition of what is to be measured, ... generating or selecting the content sample, and specifying the item format and scoring system" (p.11). The primary purpose of this study was to use expert judgment to guide the selection of items to be included in a test. Note is made that the reasons for considering the participants as experts with respect to the content domain are described.

Criterion Validity

Criterion related evidence shows that test results are systematically related to some specific concurrent or future outcome (AERA/APA/NCME, 1985; Thorndike, Cunningham, Thorndike, & Hagen, 1991) The concurrent or future outcome of interest is the criterion. A high correlation between test scores and the criterion is evidence of the validity of inferring criterion performance based on scores on the given test. Thorndike et al. identified, in order of importance, four qualities desired in a criterion measure. These qualities were: (a) relevance; (b) freedom from bias; (c) reliability; and (d) availability. This study did not address criterion validity issues.

Construct Validity

Construct-related evidence of validity focuses on the question of whether the test results are in fact a true measure of the construct being assessed (AERA/APA/NCME, 1985). The AERA/APA/NCME stressed that construct of interest must be embedded in a conceptual framework, even if this framework is incomplete, that "specifies the construct, distinguishes it from other constructs, and indicates how measures of the construct should relate to other variables" (p.9). These organizations recommended that issues such as language level, test format, and administration conditions be given careful attention when considering the construct validity of inferences. They suggested that: (a) inter correlations among items can provide evidence that a single construct was measured; (b) substantial relationships to other measures of the same construct and weak relationships to measures of different constructs support specification of the given construct; and (c) interviews with test takers to explore why they responded to given items in particular ways "can yield hypotheses that enrich the definition of a construct" (p.10). Finally, the AERA/APA/NCME noted that evidence of the content and criterion related validity of inferences support the construct validity of these inferences. This study did provide evidence that will contribute to establishing the content validity of inferences drawn from data derived from the use of the instrument by: (a) locating the construct of interest--understanding of the nature of scientific knowledge--within a framework provided by a review of the literature; (b) describing the procedures used for test and item formatting; and (c) recounting the steps taken to determine the suitability of the test language for the intended test users.

Consequential Validity

Nettles and Nettles (1995) defined consequential validity as the "extent to which an assessment tool and the ways in which it is used produce positive consequences--for the teaching and learning process, and for students who may experience different educational opportunities as a result of test based placement" (p. 95). These authors elaborated on the definition of consequential validity in arguing that tests that are free of bias in a "technical sense" (p. 121) can be considered unfair, in terms of consequential validity, if part of the gap in scores between different groups can be ascribed to class, race, or gender bias. Nettles and Nettles defined instructional effects as changes in the degree to which teachers devote time to classroom activities that: (a) promote valuable learning; and (b) are responsible to individual student needs. They then said that evidence for the consequential validity of inferences focuses on desired instructional effects. This study did not address the issue of consequential validity.

Purpose

The study was designed to answer two questions: (a) Which of the propositional statements are judged by scientists and science educators to be accurate and important statements about the nature of scientific knowledge? and (b) For which item statements is there agreement among scientists and science educators as to the truth or falsity of the statement? Note is made that the questions were posed in terms of what is intellectually honest, yet appropriate for 5th-grade students. The rating of a propositional statement as accurate and important by the survey participants will be considered as support for including the proposition in a model of the nature of scientific knowledge being used to guide development of an instrument to measure this construct. Consensus among the respondents as to the truth or falsity of an item statement will be interpreted as evidence that supports inclusion of the item in the instrument.

The model of scientific knowledge was created by retaining Rubba and Andersen's (1978) six propositions and adding two new propositions. The additions state that scientific knowledge is: (a) relevant in many fields and/or endeavors; and (b) reflects the contributions of many diverse individuals. These propositions were added because of the emphasis placed on them by the AAAS in 1989, and again in 1993. Rubba and Andersen's developmental proposition was retained, instead of Cotham and Smith's (1981) tentative and revisionary propositions. The developmental proposition was judged adequate for a model aimed at 5th-grade students, a position supported by Meichtry's use of the developmental proposition in 1992. Each propositional statement was operationalized by eight item statements.

Importance

As the academy of science educators promotes an inquiry based, hands-on pedagogy as vital to developing the scientific literacy of all students (National Research Council, 1996; American Association for the Advancement of Science, 1993), others, warned the National Science Teachers Association (1992), call for a return to traditional methods that stress the memorization of facts. Empirical data on the effectiveness of hands-on inquiry based pedagogy at increasing upper elementary students' understanding of the nature of scientific knowledge will be important and useful in informing the policy decisions of school systems as they grapple with: (a) science curriculum reform; and (b) the allocation of limited resources. Data will also be valuable to the science education professorate as it participates in the education of teachers. As Shamos noted in 1995, if curricula are to be developed to promote scientific literacy, "one must have an accurate means of testing the end product" (p. 81). There is, however, no instrument available that has been shown to be the basis for valid inferences about the understanding of the nature of scientific knowledge of students below the high school level. The results of this study will be used in the development and validation of an instrument to measure this construct for students at the 5th-grade level.

Preliminary Steps

The main methodological component of this study was a survey of experts—scientists and science educators—to determine their responses to a series of propositions and statements about the nature of scientific knowledge. Several preliminary steps were conducted. Each of these steps is presented below. In the interest of continuity, the method, results, and conclusions of each piece are presented as a unit.

Plausibility Study

Two 5th- and two 6th-grade students were interviewed to determine whether students of this age are likely to possess the conceptual knowledge necessary for a Likert-type scale to be a meaningful measure of young students' understanding of the nature of science. (Though not ideal, the use of sixth grade students reflects the difficulty of obtaining permission to interview students in school settings). The interviews addressed the hypothesis that all upper elementary students' understanding of the nature of scientific knowledge might be uniformly low, and therefore produce scores of such restricted range that discrimination between different levels of understanding is not possible.

The interviews were conducted away from school with the researcher's daughter, a female friend of his daughter, and two neighborhood boys. Each interviewee was asked a series of questions about the eight propositional statements. Follow up questions were asked to determine if the young person: (a) understood the questions being asked; (b) understood the concept being explored; and (c) could give an appropriate example/elaboration/explanation of the concept. Each interview was taped and three were transcribed verbatim. Each statement in the transcribed interviews was coded to indicate whether or not the young person met the three criteria described above.

The results were encouraging. Each interviewee appeared to understand the questions and to have reasonably accurate conceptions of the nature of science. The concept of morality was an exception. All interviewees had problems with this concept, and three were unable to distinguish between deliberately and accidentally harming another person. The proposition addressing the amoral nature of scientific knowledge was retained pending results of subsequent steps in the validation process.

Initial Items

Edward's (1957) and Spector's (1992) advice was followed in the writing of statements for each proposition. Five experts (three professors of the philosophy of science, one professor of the history of science, and one science education professor) were interviewed independently, and asked to state their opinions as to the validity of the model of the nature of scientific knowledge derived from the eight propositions. The experts were also asked to respond to, and make suggestions about, the preliminary item statements. Insight gained from the interviews was used to write eight statements for each proposition.

Suitability Study

The proposed statements were reviewed by an elementary reading specialist, and her suggestions were used to rewrite several items. The statements were compiled into a questionnaire, and sent to 50 5th-grade teachers in a variety of urban and suburban schools. Participants were asked to rate the suitability of 64 potential item statements for use with 5th-grade students using a six point scale. On this scale, 1 meant that under 55%, 6 that over 95%, of 5th-graders would be able to read and understand a given item. Participants were also asked to circle problem words and/or phrases and to suggest alternatives.

Nineteen teachers responded to the survey. Items with a mean score less than 5.0 (5 equaled 86% to 95% of 5th-graders able to read and understand the statement) were judged to be unacceptable. Twenty-nine such statements were identified. Problem words and phrases were tabulated.

A second reading specialist reviewed the survey results, and her suggestions were used in rewriting problem statements. The reworded items were resubmitted to the 19 original teacher respondents. The instructions were changed to state that the test administrator would read the statements aloud during administration of the instrument. Fourteen teachers responded to the resurvey. Four of the rewritten items produced mean scores below the target of 5.0. Three of the four problem items probed the morality/ immorality of the ways scientific knowledge is developed and/or applied compared to the knowledge itself. Two of these statements were reworded to replace the words moral and/or immoral with the phrase "harm people, animals, or the environment," a phrase that had been judged acceptable in other statements. Two problem items—(a) the things scientists do to learn new knowledge should not be judged by whether these things hurt people, animals or the environment; and (b) given the choice between two explanations for a natural event, scientists will choose the more complicated one—were retained unchanged. The decision to retain or eliminate these two items was postponed until more data are available from future steps in the validation process.

Preliminary Expert Survey

The preliminary expert survey was conducted as a test of the proposition and item statements. Surveys, with an explanatory cover letter and a stamped, return envelope were placed in the mailboxes of science professors at three local universities and one local college. The husband of one of the researcher's M.Ed. students distributed surveys to fellow scientists at his work place, a unit of the National Institutes of Health. The secretary of the science education department at a nearby university, contacted by phone, distributed surveys to science education faculty. Twenty-five university scientists, ten agency scientists, and six professors of science education responded.

The scale provided for responding to the proposition statements (1 equaled accurate and important; 2 equaled accurate and moderately important; 3 equaled accurate but unimportant; and 4 equaled inaccurate and/or misleading) was judged to be invalid because of confounding of accuracy and importance and was changed in the main survey. Despite this problem, a low mean score was interpreted as an indication that experts were reacting favorably to a propositional statement whereas a high mean score indicated an unfavorable response. Based on this interpretation, the propositions that scientific knowledge is amoral, parsimonious, and unified were problematic.

Of 64 items statements tested, the responses of the first 31 participants indicated that 50 items met the consensus criterion of a mean item score in the ranges 1.0 to 2.5 or 6.5 to 8.0 on a scale on which 1 equaled definitely true, and 8 equaled definitely false. Based on the responses of these participants, 12 new statements were added as alternatives to the problem items. With 10 scientists responding to the alternates, six of the new items met the consensus criteria. The preliminary survey, therefore, identified a total of 46 items for which there appeared to be consensus among scientists as to the truth or falsity of the items.

Method

Based on the results of the preliminary study, 16 items were either rewritten or reworded and added to the 47 that had met the consensus criteria established for the preliminary study. Two items which had narrowly missed the consensus criteria were retained unchanged. Note that the eight propositions are numbered 1-8, and the 64 item statements are numbered 9-72.

Recruiting Participants

The study was designed to survey scientists working in three environments—universities, agencies, and industry—and science education faculty. National Institutes of Health (NIH) Laboratories and National Laboratories were contacted by telephone, the study explained, and permission was sought to submit the survey, either electronically or by hard copy, to scientists at the particular institution. A directory of research and technology was used to identify Georgia and national companies that employ doctoral level persons in research and development. As with the agencies, these businesses were contacted by telephone, the study explained, and permission was sought to submit the survey to the scientists. Whether sent by mail or electronically, the survey packet included a cover letter explaining the study, a letter of support from the researcher's major professor, and the survey itself.

To recruit university scientists and science educators, the physics, chemistry, biology/ biological science, geology/geological sciences and science education departments of large universities were contacted by phone and asked to either provide the e-mail address of the faculty and post-doctorates, or to identify one person who would agree to receive the survey packet electronically and then distribute it within the department.

To increase the participation of science educators, the survey packet was distributed at the 1996 conference of the Southeastern Association of Educators of Teachers in Science (SAETS). A follow-up message was posted to the SAETS list server encouraging members to complete the survey, or to contact the researcher to receive the survey electronically. The survey packet was also distributed electronically on the list server of the Association of Educators of Teachers in Science, and forwarded to the list server of the National Association of Research in Science Teaching (NARST). An e-mail message briefly describing the study and stating the problem of the small number of responses from science educators was sent to NARST members listed in the 1995 directory with an address that included a reference to an education department, and for whom an e-mail address was given. The message asked recipients to respond if they were willing to participate in the study. The survey packet was sent to those who signaled their willingness to participate.

Proposition Statements

Respondents were asked to respond to the eight propositions by indicating their agreement or disagreement that each is an: (a) accurate; and (b) important statement about the nature of scientific knowledge. A six point scale was used for both constructs (accuracy and importance). On this scale, 1 equaled strongly agree, 2 equaled agree, 3 equaled weakly agree, 4 equaled weakly disagree, 5 equaled disagree, and 6 equaled strongly disagree that the statement is accurate/ important. Participants were asked to think in terms of what is intellectually honest, but appropriate for 5th graders; that is, children ages 10 and 11. Mean scores for accuracy and importance were calculated. To be retained in the model, a mean accuracy score and a mean importance score of less than 3.0 were prescribed.

Item Statements

Participants used an eight point scale to voice their opinion as to the truth or falsity of each item. On this scale, 1 equaled definitely true, 2 equaled true, 3 equaled mostly true, 4 equaled more true than false, 5 equaled more false than true, 6 equaled mostly false, 7 equaled false, and 8 equaled definitely false. Participants were instructed to: (a) think in terms of what is intellectually honest, but appropriate for 5th grade students; (b) distinguish between the methods used to generate scientific knowledge, scientific knowledge itself, and the application of this knowledge; (c) interpret "test" in a broad sense to include both direct and indirect methods; and (d) distinguish between observations and interpretations.

The first step in the process of identifying items for which there was expert consensus was an examination of plots of the frequency distributions, expressed as percentages, for each item. Each graph was rated A, B, C or F. This rating was done with each item identified by number only. The following rubric was used to rate the graphs. To be rated A, the graph had: (a) all responses falling in either the 1, 2, and 3 (true) or 8, 7, and 6 categories (false); and (b) a maximum at 1 (true) or 8 (false), and a minimum at 3 (true) or 6 (false). B graphs had: (a) a maximum at 1 or 2 (true), or 8 or 7 (false); (b) less than 10% of responses at the 5 plus 6 marks (true) or 4 plus 3 marks (false); and (c) no response at 7 or 8 (true) or 1 or 2 (false). Graphs rated C did not meet the criteria for A or B graphs but did show evidence that a majority of respondents agree to the truth or falsity of the item. Graphs that did not meet the criteria to be rated A, B, or C were designated F. The mean response scores were calculated in the second step of identifying items for which there was consensus.

The best items were identified as those which had been given an A rating for the frequency distribution graph and had a mean response score of less than 2.0 or greater than 7.0. Statements with mean scores less than 2.5 or greater than 6.5 with a frequency distribution rated as B or higher were designated better items. Items rated C or higher and with mean score less than 2.7 or greater than 6.3 were deemed good items. Those items that were either not given at least a C rating or which had a mean score between 2.7 and 6.3 were judged to not meet the prescribed standard for content validity.

Follow-Up Study

Because a Likert scale survey provides no insight into why participants responded in a given way, a follow-up study was conducted to probe items that produced polarized responses; that is, items for which the frequency distribution for response was U-shaped or flat. Three items, two from the testable proposition and one from the creative proposition have been included in the follow-up study to date. The testability statements were items 11 and 38. Item 11 stated that all scientific knowledge can be tested; item 38 said that some scientific knowledge can never be tested. The creative item asserted that scientific explanations are discovered in nature, not created by scientists. Participants who had responded to these items with 1's and 2's, or 8's and 7's, were contacted by e-mail, informed of the polar responses to the item, and invited to explain their response. Participants were told that the opposing viewpoints would be distributed anonymously to the other respondents. Participants were informed that they would again be invited to respond.

The first round of responses to the testable/not testable and created/discovered issues have been received, analyzed, and incorporated into this study. First round responses have been sent to participants. Reactions to these summaries are being received, but these data are incomplete and are not included in the study as reported at this time.

Group Differences

The second purpose of this study was to explore differences in the nature of scientific knowledge as seen by: (a) scientists and science educators; and (b) scientists from different environments—agency, industry, or university—and science educators, (c) scientists from different disciplines and science educators. Note that the term science educator is used to describe university based professors of education who specialize in science education; university scientists, also professors, are classified as scientists. When analysis was performed to look for these differences, four additional participants were included in the data base. Two of these were university based scientists, one of whom did not have a Ph.D. The other two were a science educator and an industry scientist.

Differences between scientists and science educators were examined in three areas: (a) accuracy responses to the propositions; (b) importance responses to the proposition statements; and (c) responses to items statements that had failed to meet the content validity criteria. The one-way between-groups MANOVA procedure, combined with the Scheffé multiple comparison test, was used to look for between-group differences. Scheffé's test was chosen because: (a) it is suitable for post-hoc comparisons; and (b) it is less likely to indicate significant differences than the Tukey or Bonferroni tests (Lomax, 1992). This conservative approach was used because of the different cell sizes in the study. The MANOVA procedure was run for the accuracy responses for the propositions, for the importance responses for the propositions, and for the items corresponding to each proposition that had not met the content validity criteria. When comparing scientists and science educators, if there was only one item to be tested for a given proposition, a t-test was used.

Limitations

The study was conducted using a Likert scale survey, and therefore suffered from all the shortcomings of this methodology. Notable among these shortcomings is the inability to gather information beyond that which was requested in the instrument. The follow-up study did attempt to address, for selected items, why respondents replied in a given way.

No claim can be made that the respondents in this study constitute a random sample. The methods used to recruit participants are described and the demographic data on the respondents are presented below.

Approximately three times as many scientists responded to the survey as did university based science educators. This imbalance in the number of respondents in the two groups means that comparison of the views of scientists and university based science educators must be interpreted with caution.

Results

Participants

Forty-five agency scientists responded to the survey, forty-three of whom had either a Ph.D. or M.D. degree. Responses were secured from 27 industry based scientists, one of whom did not have a Ph.D. Forty-four university based scientists responded, and with one exception, all had Ph.D. degrees. Thirty-eight science educators responded. Four participants were doctoral students with two describing themselves as "all but dissertation." Another science educator, an instructor at a community college, did not have a Ph.D. The other responding educators had either Ph.D. or Ed.D. degrees. One hundred and twenty-three males and 31 females participated in the study, with the largest number of females, 16, being science educators. The demographics of the respondents are presented in Tables 1 (by type and field) and 2 (type and gender) below.

Table 1.
Number of Participants by Type and Field

	Agency	Industry	University	Sci.Ed.	Total
Biological Sciences	0	2	18		20
Physics/Astronomy	7	2	6		15
Chemistry	5	12	9		26
Geological/Earth Sciences	1	1	9		11
Environmental Science	2	0	1		3
Biomedical Science	19	9	1		29
Other	8	1	0		9
Science Education	1	0	0	38	39
Missing Data	2	0	0		2
Total	45	27	44	38	154

Table 2.
Number of Participants by Type and Gender

	Agency	Industry	University	Sci.Ed.	Total
Male	37	22	42	22	123
Female	8	5	2	16	31

Validation

The primary purpose of this study was to explore the content validity of a model of scientific literacy and the item statements that operationalize the model against the opinions of scientists and science educators. The results presented below are based on the responses of all participants.

Proposition Statements

The eight proposition statements all met the a priori criterion for accuracy. This criterion was a mean accuracy score of less than 3.0 on a six point scale on which 1 equaled strongly agree, and 6 equaled strongly disagree that the proposition is an accurate statement about the nature of scientific knowledge. Five propositions resulted in mean accuracy scores below 2.0. These propositions state that scientific knowledge: (a) is developmental; (b) reflects the contributions of many diverse individuals; (c) is relevant in many fields and endeavors; (d) is testable; and (e) is the product of human creativity. Three propositions produced mean accuracy scores between 2.0 and 3.0. These statements propose that scientific knowledge is: (a) unified; (b) amoral; and (c) parsimonious. The means and standard deviations for the accuracy score for each proposition are presented in Table 3, ranked from lowest (most accurate) to highest mean. Tukey's HSD test revealed no significant difference at the 0.05 level for propositions 2, 8, 7 and 3; 7, 3 and 1; and 4, 5, and 6.

Table 3.
Accuracy of the Proposition Statements

Proposition		Accuracy	
No.	Statement	Mean	SD
2.	Scientific knowledge is developmental.	1.30 a	.77
8.	Scientific knowledge reflects the contributions of many diverse individuals.	1.48 a	.92
7.	Scientific knowledge is relevant in many fields and/or endeavors.	1.50 a b	.84
3.	Scientific knowledge is testable.	1.59 a b	.87
1.	Scientific knowledge is the product of human creativity.	1.87 b	1.17
4.	Scientific knowledge is unified.	2.48 c	1.33
5.	Scientific knowledge is amoral.	2.77 c	1.91
6.	Scientific knowledge is parsimonious.	2.82 c	1.44

N=149. A low mean score indicates a high accuracy rating. Means that do not share subscripts differed at p = .05 in the Tukey HSD comparison. (e.g., there was a significant difference between propositions 8 and 1; there was no significant difference between propositions 2, 8, 7, and 3.)

The frequency distribution of responses to the unified and parsimonious propositions were similar. Each had the greatest frequencies at the low (agreement that the statement is accurate) end of the scale and tapered off to fewer responses at the high (disagreement) end. On the unified proposition, for example, 59% of respondents either strongly agreed or agreed, 32% either weakly agreed or weakly disagreed, and 9% either disagreed or strongly disagreed that the statement is accurate. In contrast, the amoral proposition resulted in a U-shaped frequency distribution with 60% of respondents either strongly agreeing or agreeing, 13% either weakly agreeing or weakly disagreeing, and 27% disagreeing or strongly disagreeing that the statement is accurate.

Seven of the eight propositions met the importance criterion—a mean importance score less than 3.0—for inclusion in the model. Four statements had scores below 2.0 These propositions claimed that scientific knowledge is: (a) developmental; (b) relevant in many fields and endeavors; (c) testable; (d) a reflection of the contributions of many diverse individuals; and (e) a product of human creativity. Three propositions scored between 2.0 and 3.0. These stated that scientific knowledge is: (a) a product of human creativity; (b) unified; and (c) parsimonious. The mean score for the amoral proposition was 3.05, just above the prescribed criterion. The means and standard deviations for the propositional importance scores are presented in Table 4, ranked from lowest mean (most important) to highest mean. Tukey's HSD test revealed no significant difference at the 0.05 level between propositions 2, 7, 3 and 8; 8 and 1; and 4 and 6.

Table 4.
Importance of the Proposition Statements

Proposition		Importance	
No.	Statement	Mean	SD
2.	Scientific knowledge is developmental.	1.57 a	.87
7.	Scientific knowledge is relevant in many fields and/or endeavors.	1.63 a	1.00
3.	Scientific knowledge is testable.	1.67 a	1.01
8.	Scientific knowledge reflects the contributions of many diverse individuals.	1.74 a b	1.11
1.	Scientific knowledge is the product of human creativity.	2.07 b	1.10
4.	Scientific knowledge is unified.	2.56 c	1.31
6.	Scientific knowledge is parsimonious.	2.64 c	1.32
5.	Scientific knowledge is amoral.	3.05	1.71

N=148. A low mean score indicates a high importance rating. Means that do not share subscripts differed at p = .05 in the Tukey HSD comparison.

The frequency distribution for the amoral proposition responses was again different from the others. The other propositions had the greatest frequencies at the low (agreement that the statement is accurate) end of the scale and tapered off to fewer responses at the high (disagreement) end. In contrast, the distribution for the amoral proposition was approximately flat, with maxima of 25% and 24% at 1 (strongly agree) and 3 (weakly agree). Fifteen percent of participants agreed (response choice 2) that the amoral proposition was important. Therefore, although the amoral proposition failed to meet the importance standard, 64% of the respondents indicated that they at least weakly agreed that the amoral proposition is an important statement about the nature of scientific knowledge.

Summary

Based on the a priori criteria for mean accuracy and importance scores, seven of the eight propositions were eligible for inclusion in the instrument. The eligible propositions can be categorized into two groups according to their mean accuracy and importance scores. The group with higher ranked accuracy and importance consists of the propositions that scientific knowledge is: (a) developmental; (b) relevant in many fields and/or endeavors; (c) the product of the contributions of many diverse individuals; (d) testable; and (e) the product of human creativity. Two propositions formed a second group with lower rated accuracy and importance: these state that scientific knowledge is: (a) parsimonious; and (b) unified.

The eighth proposition—that scientific knowledge is amoral—was ineligible based on the prescribed criteria. Its mean importance score of 3.05 was just over the limit of 3.0 on a six point scale for which a high score indicated low importance.

Item Statements

Forty-five items met the prescribed content validity standard. Fifteen items were in the best, 12 in the better, and 18 in the good categories. The items that met the standards are presented in Tables 5-10. Table 11 displays those items that did not satisfy the content validity criteria.

Table 5.
Best True Items

Proposition	Item	Graph	Mean	S.D.
Developmental	28. Scientific knowledge can change over time.	A	1.52	.95
	50. Sometimes things that scientists thought were right turn out to be wrong.	A	1.49	.96
Relevant	32. Scientific knowledge can be useful away from school.	A	1.50	.95
	64. Scientific knowledge can be used in many different helpful ways.	A	1.69	.94
Diverse	29. Many different people often work together to discover important new knowledge in science.	A	1.66	1.03
	51. Many different kinds of people can be good scientists.	A	1.46	.90
	71. People of all races have contributed to science.	A	1.58	.02

Table 6.
Best False Items

Proposition	Item	Graph	Mean	S.D.
Developmental	36. Scientists never try to show that other scientists are wrong.	A	7.29	1.25
Testable	59. Scientists are not expected to share their discoveries with other scientists.	A	7.42	.80
Relevant	14. Science is only important in school.	A	7.75	.60
	22. Scientific knowledge will be of no use in most jobs in the future.	A	7.20	1.10
	52. The things you learn in science will be of no help to you when you finish school.	A	7.31	1.15
	72. Scientific knowledge is only useful to scientists.	A	7.58	.70
Diverse	23. Only people of certain races have helped discover scientific knowledge.	A	7.41	1.29
	60. Men make better scientists than women.	A	7.47	.99

Table 7.

Better True Items

Proposition	Item	Graph	Mean	S.D.
Amoral	21. Scientific knowledge is sometimes used in ways that hurt people, animals, or the environment.	B	2.49	1.70
Developmental	44. Some of the explanations now used in science will be changed in the future.	B	1.75	1.11
	68. Scientists often disagree with each other.	B	2.07	1.40
Relevant	42. Science will be an important part of the solution to many of the problems our country faces.	B	2.16	1.49
	47. Knowing science helps people understand the world.	B	1.94	1.28
Unified	17. Scientific knowledge from one science, like life science, is connected to knowledge from other sciences, like earth or physical science.	B	2.01	1.14
	58. The different sciences, like earth, life, and physical science, are all connected to each other.	B	2.24	1.35

Table 8.

Better False Items

Proposition	Item	Graph	Mean	S.D.
Testable	20. One experiment is all that is needed to show that a new scientific idea is right.	B	7.32	1.10
Creative	35. All good scientists work in exactly the same way.	B	7.08	1.22
Parsimonious	13. Given the choice between two scientific explanations for a natural event, scientists will most likely believe the more complicated explanation.	B	6.46	.36
Unified	31. A fact that is correct in one science can be wrong in another science.	B	6.63	1.66
	41. The different types of science, like life science and earth science, are not connected to each other.	B	6.92	1.33

Table 9.
Good True Items

Proposition	Item	Graph	Mean	S.D.
Amoral	09. Scientific knowledge is sometimes discovered in ways that hurt people, animals, or the environment.	C	2.70	1.70
	54. Scientific knowledge itself cannot harm people, animals, or the environment.	C.	2.32	1.62
Testable	56. To be useful in science, an experiment must give similar results when repeated.	C	2.16	1.56
	67. Scientific knowledge is based on repeated tests.	C	2.36	1.17
Creative	16. A good imagination is important when doing science.	C	2.46	1.26
	46. Using science to discover new things takes creativity.	C	2.49	1.21
	57. Scientific knowledge is a product of the human mind.	C	2.47	1.69
Diverse	45. Being ready to keep working on a problem is as important as being really smart for people who want to get jobs in science.	C	2.41	1.08
Unified	18. The knowledge from all the different sciences is connected.	C	2.55	1.39

Table 10.
Good False Items

Proposition	Item	Graph	Mean	S.D.
Amoral	27. Scientific knowledge itself can hurt people, animals, or the environment.	C	6.39	2.05
	61. The way scientific knowledge is used should not be judged on whether it hurts people, animals, or the environment.	C	6.80	1.81
Developmental	19. Once scientists have explained something, they know they are right.	C	6.50	1.57
	48. Scientists prefer complicated scientific explanations to simple ones.	C	6.59	1.17
	63. Scientific knowledge is true beyond doubt.	C	6.63	1.66
Creative	25. It is hard for people with lots of imagination to be good scientists.	C	6.91	1.46
Diverse	15. Only really smart people ever help find new scientific information.	C	6.31	1.63
Unified	30. Science is made up of many parts that are not connected to each other.	C	6.27	1.68
	69. Earth science and life science are totally different kinds of knowledge.	C	6.54	1.55

Table 11.
Items Not Resulting in Consensus

Proposition	Item
Amoral	37. Scientific explanations cannot be judged as good or bad based on if they can be used to hurt people, animals, or the environment.
	49. The things scientists do to learn new knowledge should not be judged by whether these things hurt people, animals or the environment.
	70. Scientific knowledge is bad if it is used to hurt people
Developmental	10. We can be sure that science always gives the right answers to questions about nature.
Testable	11. All scientific knowledge can be tested.
	26. New scientific knowledge will not be accepted until it has been tested many times.
	38. Some scientific knowledge can never be tested.
	53. Scientists will not believe a new scientific explanation unless there are test results that agree with it.
Creative	12. Good scientists are creative people.
	43. Most of the big ideas in science come from people who follow the rules.
	66. Scientific explanations are discovered in nature, not created by scientists.
Parsimonious	24. Scientists try to find simple scientific explanations for what happens in nature.
	34. Scientists try to use as few explanations as possible when describing nature.
	39. Given a choice between two explanations for something, scientists will choose the more simple explanation.
	55. Scientists want many different explanations for their observations.
	62. Scientists prefer simple scientific explanations to complicated ones.
	65. Scientists want many different explanations of why something happens in nature.
Diverse	40. Scientists have to be much smarter than lawyers, doctors, or teachers.
Unified	33. All the different things that have been learned through science are connected to each other.

Scientific Knowledge as Testable

Two items relating to the testability of scientific knowledge failed to meet the content validity criteria. These two items were included in the follow-up study being done to gain insight into interesting instances of non-consensus.

All scientific knowledge is testable. At a point in the data collection when 140 responses had been received, 16 participants had responded that: (a) item 11—all scientific knowledge is testable—is either definitely true or true; and (b) item 38—some scientific knowledge can never be tested—is either definitely false or false. Twelve of these respondents had provided valid e-mail addresses. Of these 12, 11 responded to an invitation to share their thinking on the testability of science. The common theme to their responses was that, by definition, scientific knowledge is testable. Arguments included "if it is scientific, it is testable" (agency scientist), "knowledge that cannot be tested strikes me as much closer to faith than science" (university scientist), "it is the testable nature and the empirical evidence that separate science from other ways of knowing" (science educator), "observations that cannot be repeated or theories that cannot be tested would fall outside of what I consider to be scientific knowledge" (agency scientist).

An agency scientist noted that the intended audience for the instrument under development was crucial to his response. He stated that 5th-graders can understand: (a) the difference between direct and indirect tests; and (b) that logical consistency is not adequate in science, scientific knowledge must involve the physical world; that is, be testable.

Not All Scientific Knowledge is Testable. Eight respondents answered that item 11 is definitely false, or false and that item 38 is definitely true or true. Another seven respondents joined this group when the responses were extended to include mostly false and mostly true. One of the respondents in this second group did not give an e-mail address. Six participants provided an explanation of their reasoning on the testability items. Reasons fell into three categories. The first category focused on the issue of direct testability. For example, a university scientist wrote that "the origin of life on earth will never be known as an observed event." An agency scientist gave the example that we do not have gas samples from the sun. The second category resulted from interpreting test to mean prove. This is illustrated by the argument that "it is highly doubtful, due to necessarily fragmentary fossil evidence, that scientists will ever be able to prove a particular scenario of human evolution" (university scientist). The third cluster hinged around the inclusion of all scientific theories as examples of scientific knowledge. A university scientist, using cosmology as an example, stated that "there may well come a time when two alternative models make predictions that cannot be tested because it is simply impossible to make the relevant measurements."

Scientific Explanations: Discovered or Created?

With 144 responses received, 30 participants indicated that the statement that scientific explanations are discovered in nature, not created by scientists (item 66) is either definitely true or true. The 20 who provided valid e-mail addresses and had not been asked to elaborate on the testability items were invited to explain their response to this item. Seven provided explanations. Thirty-four respondents gave the opposite response to item 66. Twenty-three of these participants were asked to discuss their response to this item, and 12 complied.

Discovered. The reasons given for answering that it is true to state that scientific explanations are discovered, not created, fell into two camps. The first camp made no distinction between explanation and observation; the second emphasized that scientific explanations must be consistent with nature and that the word create implies fabricate.

Evidence for the equating of explanation and observation included the comment by an agency scientist that natural phenomena are not created by the scientist, only the words used to explain the phenomena are created by scientists. A second agency scientist observed that scientists put explanations into words "but the explanation itself is a reality." As an illustrative example, he observed that "gold does not exist because someone discovered it any more than its specific gravity is greater than silver's because it was articulated as such." A university scientist stated that the key to his response was the meaning of the word explanation. He interpreted explanation as referring to the "fundamental relationships that make up a scientific 'truth'" and asserted that "these relationships are discovered by scientists as they examine nature." This respondent noted that if explanations are read as "the verbalized descriptions of these relationships, the verbal constructs themselves clearly are created by the writer/speaker."

Illustrating the concern that create implies fraud, a university scientist wrote that "scientists don't create explanations but rather they use the information acquired in nature to develop an explanation." A second university scientist reported that he interpreted the item to state that "natural observations (and experimentation) lead to scientific explanations and that scientists do not create (fabricate or make up) the explanations in isolation."

Created. An industry scientist wrote that whereas science is grounded in nature, "nature does not supply scientists with explanations for how and why it works the way it does; scientists, after observing and measuring nature, create possible explanations." A science educator stated his belief that it is false to assert that scientific explanations "are lying around in nature waiting for scientists to pick them up." An agency scientist wrote that "nature does not explain anything, scientists do all the explaining." This position was echoed by a science educator who stated that he was "not sure what is discovered in nature, but it is certainly not explanations" which, he asserted, "are created in the mind."

A university scientist stated that scientific explanations are "essentially models that are consistent with observations and measurements" and said that they are the products of scientific minds using inductive and deductive reasoning. To support his contention, this respondent provided an example from his fieldwork in Africa. A local tribe, whose members' lives were intimately intertwined with nature, observed that the huge nests of the Hammerkopp, a small bird, overhang the river but do not get flooded. "The local natives deduced that because the Hammerkopp nests do not flood, the bird must control the height of the river. Therefore each year the local medicine man captures a Hammerkopp and stakes it to the riverbank to control the height of the flood. This tribe has made little progress in flood prognostication over the last 10,000 years." The respondent used this example to illustrate his contention that "scientific discovery is not made by the simple act of observing. While observations are an essential prerequisite, scientific discovery is the product of a framework of carefully organized thought, critical thinking and model development."

Group Differences

A second purpose of this study was to explore differences in the perception of the nature of scientific knowledge between different groups. Scientists and science educators (kind) were compared. Scientists were also grouped in two ways: (a) by working environment—agency, industry, or university (type); and (b) by discipline (field). The groups of scientists were compared to each other and to science educators.

Scientists versus Science Educators (Kind)

In this analysis all responding scientists were placed into one group. Scientists and science educators were then compared for differences in their rating of the accuracy of the propositions, the importance of the propositions, and their responses on items that failed to meet the content validity criteria.

Accuracy of the Proposition Statements

The data on the accuracy of the proposition statements were analyzed using a one-way MANOVA between-groups design. The analysis revealed a significant multivariate effect in the comparison of scientists and science educators—Wilk's Lambda = .87, $F = 2.57$ (8, 147); $p = .01$. The individual ANOVA results showed that a single variable—proposition 8, which states that scientific knowledge reflects the contribution of many diverse individuals—was significantly different. The ANOVA results are summarized in Table 12.

Table 12.
ANOVA Summary for Proposition 8—Kind/Accuracy

	Scientific Knowledge Reflects the Contributions of Many Diverse Individuals				
Source	df	SS	MS	F	R^2
Kind	1	5.32	5.32	6.59 *	.04
Error	149	120.35	.81		
Total	150	125.67			

*$p = .01$

Scheffé's multiple comparison test also identified proposition 8 as the only proposition with a significant difference between the means for the accuracy score of the two groups. The means were 1.37 (scientists) and 1.79 (science educators) and are presented, with standard deviations, in Table 13. Seventy one percent of scientists strongly agreed, 25% agreed, and 1% weakly agreed that proposition 13 is an accurate statement. The corresponding data for science educators were 59%, 18%, and 18%.

Table 13.
Means and Standard Deviations for Proposition 13—Kind/Accuracy

	Scientific Knowledge Reflects the Contributions of Many Diverse Individuals		
Group	N	Mean	SD
Scientists	112	1.37	0.74
Science Educators	39	1.79	1.26

Means are significantly different based on Scheffé's multiple comparison test.

Importance of the Proposition Statements

The MANOVA procedure revealed an overall significant difference between scientists and science educators with respect to the importance of the eight proposition statements—Wilk's Lambda = 0.73, F = 6.36 (8, 140); p = .0001. The ANOVA results identified proposition 1—scientific knowledge is the product of human creativity—and proposition 5—scientific knowledge is amoral—as producing significantly different means for scientists and science educators. The ANOVA results are displayed in Tables 14 and 15. Scheffé's multiple comparison test echoed this finding. The means and standard deviation are shown in Table 16, the frequency distribution (expressed as percentages) in Table 17.

Table 14.
ANOVA Summary for Proposition 1—Kind/Importance

	Scientific Knowledge is the Product of Human Creativity				
Source	df	SS	MS	F	R^2
Kind	1	22.25	22.25	22.94*	.13
Error	147	142.59	.97		
Total	148	164.83			

*p = .0001. Two classes of Kind: Scientists and Science Educators

Table 15.
ANOVA Summary for Proposition 5—Kind/Importance

	Scientific Knowledge Itself is Amoral				
Source	df	SS	MS	F	R^2
Kind	1	33.84	2.66	12.66*	.08
Error	147	393.10	1.69		
Total	148	426.94			

*p = .0005. Two classes of Kind: Scientists and Science Educators.

Table 16.
Means and Standard Deviations for Propositions 1 and 5 — Kind/Importance

Kind	N	Proposition 1 Creative Mean	SD	Proposition 5 Amoral Mean	SD
Scientists	110	2.26	1.08	2.74	1.67
Science Educators	39	1.38	.63	3.82	1.52

Two classes of Kind: Scientists and Science Educators. N (Scientists) = 110; N (Science Educators) =39. Means for a given proposition are significantly different based on Scheffé's multiple comparison test.

Table 17.
Frequency Distribution of Responses for Propositions 1 and 5 — Kind/Importance

	Proposition 1 Creative Scientists	Sci. Ed.	Proposition 5 Amoral Scientists	Sci. Ed.
Strongly Agree	29	69	31	8
Agree	30	23	20	8
Weakly Agree	30	8	20	33
Weakly Disagree	8		11	18
Disagree	2		7	13
Strongly Disagree	2		12	21

Two classes of Kind: Scientists and Science Educators. N (Scientists) = 110; N (Science Educators) = 39. Frequencies expressed as percentages.

Item Statements

The amoral, testable, creative, and parsimonious propositions all had more than one item that failed to meet the content validity standards. When the group of items corresponding to a particular proposition were tested using the MANOVA procedure, there were no significant differences. The developmental, diverse, and unified propositions each had a single item that did not satisfy the content validity criteria. T-tests for each of these items indicated that there was a significant difference ($\underline{p}$ = .009) between scientists and science educators for the developmental item—we can be sure that science always gives the right answers to questions about nature (item 10). The mean and standard deviation for scientists (N = 139) were 5.68 and 1.94, and for science educators (N = 39) they were 6.54 and 1.65. There was no significant difference for either the diverse or the unified item.

Scientists by Environment and Science Educators (Type)

For this analysis, the scientists were broken down into three groups—agency, industry, and university scientists. The three groups of scientists and science educators were compared.

Accuracy of the Proposition Statements

The MANOVA procedure revealed a significant multivariate difference ($p = .02$) for the comparison of the three groups of scientists and science educators. The ANOVA results showed a significant between-groups difference for propositions 1—scientific knowledge is the product of human creativity ($p = .05$); 6—scientific knowledge is parsimonious ($p = .04$); and 8—scientific knowledge reflects the contributions of many diverse individuals ($p = .04$). Scheffé's test, however, failed to reveal any significant between-groups differences.

Importance of the Proposition Statements

The MANOVA procedure revealed a significant multivariate difference—Wilkes Lambda = 0.59, $F = 3.35$ (24, 401); $p = 0.0001$. Propositions 1 (creative), 3 (testable), and 5 (amoral) were shown to exhibit significant between-group differences. The ANOVA results for these three variabies are summarized in Tables 18, 19, and 20.

Table 18.

ANOVA Summary for Proposition 1—Type/Importance

	Scientific Knowledge is the Product of Human Creativity				
Source	df	SS	MS	F	R^2
Type	3	26.62	8.87	9.31*	.16
Error	145	138.21	.95		
Total	148	164.83			

*$p = .0001$. Four classes of Type: Agency, Industry and University Scientists, and Science Educators.

Table 19.
ANOVA Summary for Proposition 3—Type/Importance

		Scientific Knowledge is Testable			
Source	*df*	*SS*	*MS*	*F*	R^2
Type	3	9.76	3.26	3.68*	.07
Error	145	128.38	.89		
Total	148	138.15			

*p = .01. Four classes of Type: Agency, Industry and University Scientists, and Science Educators.

Table 20.
ANOVA Summary for Proposition 5—Type/Importance

		Scientific Knowledge Itself is Amoral			
Source	*df*	*SS*	*MS*	*F*	R^2
Type	3	45.85	15.28	5.82*	.11
Error	145	381.09	2.63		
Total	148	426.94			

*p = .0009. Four classes of Type: Agency, Industry and University Scientists, and Science Educators.

The Scheffé test identified significant differences between science educators and agency scientists, and science educators and industry scientists on the importance of the creativity proposition. There were also significant differences between: (a) industry and university based scientists with respect to the importance of the testability proposition; and (b) science educators and university scientists on the importance of the amoral proposition. The data are displayed in Tables 21 (means and standard distributions) and 22 (frequency distributions).

Table 21.
Means and Standard Deviations for Propositions 1, 3 and 5 — Type/Importance

Type	N	Proposition 1 Creative Mean	SD	Proposition 3 Testable Mean	SD	Proposition 5 Amoral Mean	SD
Agency	44	2.41 a	1.26				
Industry	26	2.42 a	.76	2.08	1.02		
University	40			1.30	.65	2.33	1.53
Sci. Ed.	39	1.38 b	0.63			3.82	1.52

Four classes of Type: Agency, Industry and University Scientists, and Science Educators. Means followed by different letters are significantly different based on Scheffé's multiple comparison test.

Table 22.
Frequency Distribution of Responses for Propositions 1,3 and 5 — Type/Importance

	Proposition 1 Creative Agn^{a}	Ind^{a}	Uni	Edu^{b}	Proposition 3 Testable Agn	Ind	Uni	Edu	Proposition 5 Amoral Agn	Ind	Uni	Edu
Strongly Agree	27	11		69		30	78				43	8
Agree	31	41		23		41	18				23	8
Weakly Agree	22	44		8		19	3				12	33
Weakly Disagree	11	4				4	3				7	20
Disagree	4					7					13	13
Strongly Disagree	4										2	20

Four classes of Type: Agency, Industry and University Scientists, and Science Educators. Frequencies expressed as percentages. Significant difference between types with different superscript letters based on Scheffé's multiple comparison test.

Item Statements

The MANOVA test to compare groups of items by proposition found no significant difference for the items under the amoral, creative, developmental, and diverse propositions. Significant multivariate difference were found for items representing the testable, parsimonious, and unified propositions.

Testable. There were four items from the testable proposition that did not show consensus. The MANOVA test of these items indicated a significant difference—Wilk's Lambda = 0.96, F = 2.48 (12, 397); p = .004. The ANOVA results, summarized in Table 23, identified item 26—new scientific knowledge will not be accepted until it has been tested many times—as the source of this difference. Scheffé's multiple comparison test located significant differences between university scientists and agency scientists, university scientists and industry scientists, and industry scientists and science educators. The means and standard deviations are presented in Table 24, the frequency distribution in Table 25.

Table 23.
ANOVA Summary for Item 26—Type

	New Scientific Knowledge will not be Accepted Until it has been Tested Many Times				
Source	df	SS	MS	F	R^2
Type	3	51.83	17.28	6.78*	.12
Error	153	389.93	2.55		
Total	156	441.77			

*p = .0003. Four classes of Type: Agency, Industry and University Scientists, and Science Educators.

Table 24.
Means and Standard Deviations for Item 26 — Type

	New Scientific Knowledge will not be Accepted Until it has been Tested Many Times		
Type	N	Mean	SD
University	46	2.43 a	1.33
Sci. Ed.	39	2.64 a	1.50
Agency	44	3.48 b	1.87
Industry	28	3.89 b	1.66

Four classes of Type: Agency, Industry and University Scientists, and Science Educators. Means followed by different letters are significantly different based on Scheffé's multiple comparison test.

Table 25.
Frequency Distribution of Responses for Item 26 — Type

	New Scientific Knowledge will not be Accepted Until it has been Tested Many Times			
	Agn ^{b}	Ind ^{b}	Uni ^{a}	Sci.Ed. ^{a}
Definitely True	11		26	23
True	24	29	35	28
Mostly True	24	18	22	28
More True than False	20	18	9	13
More False then True	2	14	4	3
Mostly False	9	14	4	3
False	4	7		3
Definitely False	4			3

Four classes of Type: Agency, Industry and University Scientists, and Science Educators. Significant difference between types with different superscript letters based on Scheffé's multiple comparison test.

Parsimonious. Six items from the parsimonious proposition failed to meet the content validity standards. The MANOVA test of this group of items indicated a significant difference—Wilk's Lambda = 0.78, F = 2.11 (18, 419); p =.006. According to the ANOVA results, three of these items produced significant differences. These were items 24—scientists try to find simple scientific explanations for what happens in nature; 39—given a choice between two explanations for something, scientists will choose the more simple explanation; and 62—scientists prefer simple scientific explanations to complicated ones. The ANOVA summaries for these items are shown in Tables 26, 27, and 28.

Table 26.
ANOVA Summary for Item 24—Type

	Scientists Try to Find Simple Scientific Explanations for what Happens in Nature				
Source	df	SS	MS	F	R^2
Type	3	23.54	7.85	2.98*	.06
Error	153	403.38	2.64		
Total	156	426.92			

*p = .034. Four classes of Type: Agency, Industry and University Scientists, and Science Educators

Table 27.
ANOVA Summary for Item 39—Type

	Given a Choice Between Two Explanations for Something, Scientists will Choose the More Simple Explanation				
Source	df	SS	MSF	F	R^2
Type	3	34.55	11.52	3.57*	.07
Error	153	493.47	3.23		
Total	156	523.03			

p = .016. Four classes of Type: Agency, Industry and University Scientists, and Science Educators

Table 28.
ANOVA Summary for Item 62—Type

	Scientists Prefer Simple Scientific Explanations to Complicated Ones				
Source	df	SS	MS	F	R^2
Type	3	61.99	20.66	7.72*	.13
Error	153	409.64	2.68		
Total	156	471.63			

p = .0001. Four classes of Type: Agency, Industry and University Scientists, and Science Educators

There were significant differences, according to the Scheffé test, between: (a) industry and university scientists for item 24; (b) industry and university scientists for item 39; and (c) university and agency scientists, university and industry scientists, and university scientists and science educators for item 62. See Table 29 for means and standard deviations, and Table 30 for frequency distributions.

Table 29.
Means and Standard Deviations for Item 24, 39, and 62 — Type

		Item 24		Item 39		Item 62	
Type	N	Mean	SD	Mean	SD	Mean	SD
Agency						3.31 a	1.96
Industry	28	3.43	1.57	4.18	1.87	3.29 a	1.88
University	45	2.31	1.44	2.80	1.69	1.87 b	.77
Sci. Ed.						3.15 a	1.77

For Items 24 and 39, means for each item are significantly different based on Scheffé's multiple comparison test. For Item 62, means followed by different letters are significantly different based on Scheffé's multiple comparison test.
Item 24: Scientists try to find simple scientific explanations for what happens in nature.
Item 39: Given a choice between two explanations for something, scientists will choose the more simple explanation.
Item 62: Scientists prefer simple scientific explanations to complicated ones.

Table 30.
Frequency Distribution of Responses for Item 24, 39, and 62 — Type

	Item 24				Item 39				Item 62			
	Agn	Ind	Uni	Sci.Ed.	Agn	Ind	Uni	Sci.Ed	Agn	Ind	Uni	Sci.Ed
Definitely True			26				15		13	14	30	5
True		39	35			21	39		13	29	54	49
Mostly True		21	22			25	24		20	14	9	18
More True than False		14	9			14	11		27	25	7	5
More False then True		14	4			11			11	7		10
Mostly False		4	4			18	7		9	4		5
False		7				4			4			5
Definitely False						7	4		2	7		3

Frequencies expressed as percentages.

Unified. The one item from the unified proposition—all the different things that have been learned through science are connected to each other (item 33)—that did not meet the content validity conditions produced a significant difference on the univariate test. The results are displayed in Table 31.

Table 31.
ANOVA Summary for Item 33—Type

	All the Different Things that have been Learned Through Science are Connected to Each Other				
Source	df	SS	MS	F	R^2
Type	3	40.89	13.63	6.04*	.11
Error	153	345.05	2.56		
Total	156	385.94			

*p = .0006. Four classes of Type: Agency, Industry and University Scientists, and Science Educators.

Scheffé's test identified differences as occurring between university scientists and agency scientists, and university scientists and industry scientists. The relevant data are presented in Tables 32 (means and standard deviations) and 33 (frequency distributions).

Table 32.
Means and Standard Deviations for Item 33 — Type

		All the Different Things that have been Learned Through Science are Connected to Each Other	
Type	N	Mean	SD
Agency	45	3.64 a	1.76
Industry	28	3.53 a	1.48
University	45	2.40 b	1.30
Sci. Ed.			

Four classes of Type: Agency, Industry and University Scientists, and Science Educators. Means followed by different letters are significantly different based on Scheffé's multiple comparison test.

Table 33.
Frequency Distribution of Responses for Item 33 — Type

	All the Different Things that have been Learned Through Science are Connected to Each Other		
	Agn^a	Ind^a	Uni^b
Definitely True	13	4	30
True	13	25	31
Mostly True	20	25	22
More True than False	27	21	9
More False then True	11	14	7
Mostly False	9	7	2
False	4	4	
Definitely False	2		

Frequencies expressed as percentages. Significant difference between types with different superscript letters based on Scheffé's multiple comparison test.

Scientists by Discipline and Science Educators (Field)

This analysis was performed to see if there was evidence of discipline-based differences in scientists' perceptions of scientific knowledge. Five disciplines—biology, physics/astronomy, chemistry, geology, and biomedical—and science education were compared.

Accuracy of the Proposition Statements

The MANOVA results revealed no significant multivariate difference. However, both the ANOVA results and the Scheffé test indicated that there was a significant difference between biologists and chemists with respect to the accuracy of the creative proposition. A t-test of the means for biologists and chemists (1.19 and 2.40 respectively) with respect to the importance of the accuracy proposition indicated a significant difference (p = .0004). The frequency distributions for the two disciplines, shown in Table 34, appeared to differ.

Table 34.

Frequency Distribution of Responses for Proposition 1 — Field/Accuracy

	Scientific Knowledge is the Product of Human Creativity	
	Biology	Chemistry
Strongly Agree	88	36
Agree	6	20
Weakly Agree	6	24
Weakly Disagree		8
Disagree		12
Strongly Disagree		

Frequencies expressed as percentages. N(Biology) = 20, N(Chemistry)= 25

Importance of the Proposition Statements

The MANOVA procedure revealed a significant multivariate difference—Wilk's' Lambda = 0.51, F = 2.22 (40, 539); $p = 0.0001$. The ANOVAs indicated that there were significant difference for propositions 1 (creative) and 5 (amoral). The Scheffé multiple comparison test indicated a significant difference between science education and chemistry. The ANOVA results for the importance of proposition 1 are summarized in Table 35, means and standard deviations in Table 36, and the frequency distributions in Table 37.

Table 35.

ANOVA Summary for Proposition 1—Field/Importance

	Scientific Knowledge is the Product of Human Creativity				
Source	df	SS	MS	F	R^2
Field	5	22.50	4.50	4.98*	.16
Error	130	117.47	.90		
Total	135	139.47			

*$p = .0003$. Six classes of Field: Biology, Physics/Astronomy, Chemistry, Geology, Biomedicine, and Science Education

Table 36.
Means and Standard Deviations for Proposition 1 — Field/Importance

Scientific Knowledge is the Product of Human Creativity			
Field	N	Mean	SD
Chemistry	25	2.48	1.23
Sci. Ed.	40	1.45	.75

Means are significantly different based on Scheffé's multiple comparison test.

Table 37.
Frequency Distribution of Responses for Proposition 1 — Field/Importance

	Scientific Knowledge is the Product of Human Creativity	
	Chemistry	Sci. Ed.
Strongly Agree	28	68
Agree	20	23
Weakly Agree	36	7
Weakly Disagree	8	2
Disagree	8	
Strongly Disagree		

Frequencies expressed as percentages. N(Chemistry) = 25, N(Sci .Ed.) = 40

Item Statements

The item statements that did not meet the consensus criteria were tested in groups by propositions. A MANOVA indicated a significant difference ($\underline{p}$ = .03) for the three items from the creativity proposition, and the ANOVAs revealed that this difference was significant ($\underline{p}$ = .035) for item 66—scientific explanations are discovered in nature, not created by scientists—and almost significant ($\underline{p}$ = .051) for item 12—good scientists are creative people. The Scheffé test, however, failed to pinpoint the differences by field. MANOVA tests for the multiple items in the amoral, testable, and parsimonious propositions produced no significant differences. ANOVAs for the single items from the developmental, diverse, and unified propositions also produced no significant differences.

Discussion

Primary Purpose

This study was designed to provide answers to two questions. These questions were: (a) which of the eight proposed propositional statements are judged by scientists and science educators to be accurate and important statements about the nature of scientific knowledge? (b) for which of the 64 suggested item statements is there agreement among scientists and science educators as to the truth or falsity of the statement? Note is made that the questions were posed in terms of what is intellectually honest, but appropriate for 5th-grade students; that is, 10- and 11-year-olds.

Propositions

The study showed that five propositions were rated high with respect to their accuracy and importance as statements regarding the nature of scientific knowledge. These propositions were that scientific knowledge is: (a) developmental; (b) a reflection of contributions of many diverse individuals; (c) relevant in many fields and/or endeavors; (d) testable; and (e) the product of human creativity. Two additional propositions were endorsed, though less strongly, as accurate and important statements about scientific knowledge. These two propositions state that scientific knowledge is: (a) unified; and (b) parsimonious. A final proposition—that scientific knowledge is amoral—was rated accurate, but not important.

Item Statements

The study identified 45 items for which there was expert consensus as to the truth or falsity of the statement and the 19 items for which there was no consensus. The explanations provided by participants in the follow-up piece on the testability of scientific knowledge provided insight into the reasons why there was not consensus with respect to items 11 and 38. On one side, in stating that scientific knowledge must be testable, respondents identified testability as the sine qua non of scientific knowledge. On the other, those who said not all scientific knowledge must be testable equated test with prove, limited test to direct observation, or included scientific theories as a type of scientific knowledge and asserted that not all theories are testable. The items state that: (a) all scientific knowledge is testable (item 11); and (b) some scientific knowledge can never be tested (item 38). Equating test with prove in the context of these items is, I argue, unjustified; tests both support/prove and disprove. I assert that, in science, the term test has long included indirect methods. The knowledge that matter is composed of atoms was arrived at with no direct observation of atoms, yet the existence of atoms was convincingly supported by the results of indirect tests. Theories that have been supported by varied and reliable evidence and have come to be widely accepted by the scientific community may be considered scientific knowledge—though any given theory is subject to being proved inadequate or even wrong. However, a theory that cannot be tested because it is impossible to make relevant measurements is unlikely to gain general acceptance by scientists, and is not an example of scientific knowledge.

The arguments in favor of the testability of scientific knowledge are, in my judgment, simple and convincing. Testability is the essential test of scientific knowledge; the reliance on empirical evidence is what separates science from other ways of knowing. I conclude that it is unreasonable to reject the statement that all scientific knowledge is testable based on: (a) limiting tests to direct observation; (b) equating test and prove; or (c) classifying speculative, untestable theories as examples of scientific knowledge. I argue that the data from the follow-up study is more convincing than that from the survey, and conclude that the claims that: (a) all scientific knowledge is testable (true); and (b) some scientific knowledge can never be tested (false) are valid statements about the nature of scientific knowledge.

The exploration of item 66 revealed the reasons for the opposing views on the question of whether scientific explanations are discovered or created. Those in favor of scientific explanations as discoveries, not creations, either did not distinguish between observations and explanations, or interpreted create to imply fraud.

The argument that the words used to explain phenomena are created by scientists supported the opposite position, that scientific explanations are created, not discovered. The assertion that scientists put explanations into words, but that the explanations themselves are reality, illustrated by reference to the specific gravities of gold and silver illustrates the failure to discriminate between observation and explanation. Further, I reject the argument that explanations are reality. Does any scientist believe that scientific explanations are beyond revision or even rejection? How can this revision or rejection be possible if scientific explanations are reality? The scientist who made the argument that explanations are reality added that scientists do not create explanations, but use data to develop explanations. Surely a scientist who develops an explanation is creating, not discovering, it.

The meaning of explanation was crucial for another respondent. With explanation interpreted as the fundamental relationships that make up scientific truth, he argued for the discovery position. However, if explanations are interpreted as the verbalized descriptions of observed relationships, explanations are created not discovered, he said. I say the fundamental relationships observed in nature are not explanations; they are observations. Further, the verbalization of these relationships are not explanations. They are scientific laws. An explanation describes why or how these relationships exist. If the verbalization of a scientific law is a human creation, then certainly explanations are also creations.

The response, discussed above, that scientists do not create explanations, but use data to develop explanations hints at the interpretation of create to mean falsify. Another respondent explicitly identified this equating of creation and fraud. I maintain that using one's imagination to create data is indeed scientific fraud; using this same imagination to interpret and explain legitimate data is integral to the scientific process.

Those arguing that explanations are created, not discovered were, I believe, more convincing than those maintaining the opposite position. Artifacts, natural behavior and processes, and relationships exist in nature. Scientists strive to discover/observe these. The artifacts, behaviors, processes, and relationships, however, exist whether or not they are discovered or observed. Explanations, in contrast, are the result of scientists interpretation of physical evidence, and as such do not exist until created. Based on the data from the follow-up study, the conclusion is made that scientific explanations are indeed created, not discovered. However, the wording of the original statement—scientific explanations are discovered in nature, not created by scientists—is judged to be problematic. The concept will be expressed with a rewritten statement—scientific explanations do not exist until they are created by scientists. This wording will be submitted to the participants in the follow-up study, and if there is consensus as to its truth, it will be incorporated into the instrument.

Secondary Purpose

A second purpose of the study was to explore differences in the perceptions of nature of scientific knowledge among: (a) scientists and university based science educators; (b) scientists working in different environments and science educators; and (c) scientists from different disciplines and science educators. Differences were sought in the rating of the accuracy and importance of the propositions, and in responses to items that did not meet the content validity criteria.

Scientists and Science Educators (Kind)

Propositions

When respondents were broken down into scientists and science educators, there was a significant difference between the responses of the two groups with respect to the importance of the amoral proposition. Scientists produced a mean importance score (2.74) that met the a priori criterion for accepting the proposition as important. Science educators, in contrast, produced a mean score (3.82) above the acceptable cut-off on a scale for which a low score indicated a high importance rating. This result may suggest that scientists, but not science educators, believe that it is important for 5th-graders to distinguish between the amorality of scientific knowledge itself and the production and/or use of scientific knowledge that are subject to moral judgment. The ANOVA R^2 value (.08) indicates that, though significant, this result should be interpreted cautiously. Work done with 5th-grade teachers and 5th- and 6th-grade students in the preliminary stages of this study suggested that 5th-graders are likely to have difficulty understanding the amorality proposition. The difference in the responses of the scientists and the educators to the importance of this proposition may reflect a better understanding of young students by the educators than by the scientists. An additional hypothesis as to this difference is suggested when the data from scientists is broken down by working environment—agency, industry, or university.

The propositions that scientific knowledge is: (a) relevant in many fields and/or endeavors; and (b) reflects the contributions of many diverse individuals were not part of the previous models that provided the foundation for the present model. These two propositions were added to reflect emphases in the current science education reform literature. It is noteworthy that these two propositions were ranked in the top echelon with regard to both accuracy and importance by the responding experts. It is interesting that when the responses of scientists and science educators were compared, the scientists were more likely to strongly agree or agree (96%) that the proposition is accurate than were science educators (77%). This finding provides evidence that the propositions not only reflect the position of science education reformers; there may be wide acceptance and valuing by scientists of the propositions that scientific knowledge is: (a) relevant in many fields and/or endeavors; and (b) reflects the contributions of many diverse individuals.

Science educators (92%) were more likely than scientists (59%) to strongly agree or agree to the importance of the statement that scientific knowledge is a product of human creativity. When science educators focus on science content, the subject may often be the great breakthroughs in science, such as Newtonian mechanics or the unraveling of DNA. Individual scientists are more likely engaged in the incremental advancement of scientific knowledge than with the paradigm shifts that occasionally reorient the scientific world. This different perspective on scientific knowledge may explain the observed difference with respect to the creativity proposition. Science educators' interest in student motivation may also cause them to attach greater importance to the role of human creativity in producing scientific knowledge.

Item Statements

When the 19 items for which there was not consensus were tested, there was a single item on which scientists and science educators differed significantly. The statement said that we can be sure that science always gives the right answers to questions about nature (item 10). The science educators' mean score fell between mostly false and false, whereas the scientists' mean score was between more false than true and mostly false. That is, science educators were more inclined to identify the statement as false than were scientists.

During data collection, two science educators were critical of surveying scientists to establish the content validity of statements related to scientific literacy. The training and practice of working scientists were too narrow, they asserted, to qualify scientists as experts on scientific literacy. On the other hand, a scientist offered equally strong criticism for including science educators in the survey. This respondent stated that science educators know little or nothing about the scientific enterprise. In light of these criticisms, the overall similarity of the responses of scientists and science educators is interesting. There was a significant difference on the mean accuracy score for one proposition—diversity—but mean score of both groups fell between strongly agree and agree. The difference in the importance rating for the creativity proposition was significant, but both groups' mean scores were on the agree side of the scale. There was only one proposition (amoral) for which the mean importance scores of scientists and science educators fell on different sides of the midpoint of the response scale, with scientists, but not science educators, agreeing that the proposition was important in a model intended for use with 5th-graders. For the item statements, there was no significant difference on 18 of 19 items tested. The difference in the one item was significant, but modest. The other 45 items satisfied the consensus criteria and were not examined.

By Environment (Type)

Propositions

When the data were looked at by the environment—agency, industry, or university—of the responding scientists there were no significant differences on the mean accuracy scores for the propositions. There were significant differences in the mean importance score for propositions 1 (creative), 3 (testable), and 5 (amoral).

Science educators rated the creative proposition significantly more important than did either agency or industry scientists, with 92% of science educators, 58% of agency scientists, and 52% of industry scientists strongly agreeing or agreeing that the proposition is important. In discussing the difference between scientists and science educators on this variable, it was suggested that the difference might be the result of the latter group's likely focus on the paradigm shifts in science, and/or their interest in issues of student motivation. Both of these hypothesized explanations may be supported by the data showing that the position of science educators is significantly different from agency and industry scientists, but not university scientists. University scientists are likely to be teachers as well as researchers. It is reasonable to suggest that this teaching role is likely to focus, at least in part, on break-through science, and lead to a consideration of motivational factors. Agency and industry scientists, on the other hand, are less likely to teach than university scientists. Agency scientists may, therefore, be more focused than than university scientists on the incremental advance of scientific knowledge.

On the importance of the amoral proposition, science educators and university based scientists were significantly different. Science educators produced a mean score between weakly disagree and disagree, whereas university scientists rated the proposition between agree and weakly agree; 16% of science educators and 66% of university scientists strongly agreed or agreed that the proposition is important. University scientists may be more likely than either agency or industry scientists to be pursuing pure, as opposed to, applied research. If this assumption is valid, it may be reasonable to speculate that the different research focus offers an explanation of why university scientists and science educators produced significantly different mean score for the importance of this proposition. Involved in pure research, the university scientist can easily separate knowledge from the methods used in its discovery, and/or the uses to which the knowledge is put. Science educators, who must focus on motivational issues, stress the practical importance of science to individuals and society may be less likely to make the distinction. Agency and industry scientists, involved in applied research, fall between the university scientists and science educators, and produce means scores not significantly different from the mean scores of either group of professors.

With respect to the importance of the testable proposition, university scientists averaged between strongly agree and agree, whereas the mean for industry scientists fell between agree and weakly agree. Even though these means were both on the agree side of the scale, and the ANOVA R^2 was only .07, there was a statistically significant difference. This result at first seems counter intuitive. If industry scientists are more likely to be engaged in applied research than are university scientists, as has been assumed in earlier hypothesizing, it would seem reasonable to assume that industry scientists would think in terms of testable knowledge. It may be that university scientists are more likely than industry scientists to include indirect methods within their conception of "test." Unfortunately, a majority of the industry scientists who participated in the survey did not provide e-mail addresses, and so are not included in the follow-up study that is probing the issue of testability. Alternatively, compared to industry scientists, university scientists' greater acceptance of the testability of science may be a product of their role as teachers. Science professors may focus on testability as the key distinction between scientific knowledge and other types of knowledge and/or pseudo-science. Unlike their university counterparts, industry scientists likely have no reason to focus on the differences between pseudo-science and science.

Item Statements

The 19 items that did not met the content validity standards were examined for significant differences between the responses of agency, industry, and university scientists, and science educators. Five of these items produced significant differences: one item from the testable proposition, one from the unified proposition, and three from the parsimonious proposition.

Testable. Item 26—new scientific knowledge will not be accepted until it has been tested many times—received a higher true rating from university scientists and science educators than from agency and industry scientists. This result may support an earlier argument: these two groups, both comprised of teachers, may be more cognizant than their colleagues in industry or at agencies of what is appropriate for young students. Given this awareness, these respondents may be more willing than agency or industry scientists to accept what some might claim is an idealized view of the scientific process as legitimate in the given context.

Unified/Parsimonious. One item from the unified and three from the parsimonious propositions produced mean importance scores that were significantly different. Although it is difficult to speculate on the reasons for the differences, it is interesting that university scientists were different from agency and industry scientists on each of the four items. For three of the items, there was no significant difference between the university scientists and science educators. Modest R^2 ANOVA values (.06, .07, .11, and .13) suggest caution in interpreting the differences, but the data may support earlier arguments that, as teachers, university scientists hold views closer to science educators than to fellow scientists in industry or at agencies.

By Discipline (Field)

The MANOVA result showed no multivariate significant difference for the accuracy of the propositions based on the discipline of the respondents. The frequency distributions, however, may suggest that chemists are less likely to view scientific knowledge as the product of human creativity than are biologists. When the importance of the propositions was examined, chemists were less likely than science educators to rate the creative proposition as important. These results may suggest that chemists are less likely than scientists in other fields to view science knowledge as the product of human creativity. The evidence for such a conclusion, however, is very weak. No significant discipline based differences were identified for the tested item statements.

The study produced no evidence of discipline based differences in the participants' views of the nature of scientific knowledge. At first, this might appear surprising. Is physics not a very different endeavor than biology or geology? As is discussed below in looking at between-group differences in general, the model of scientific knowledge used in this study, designed for use with 5th-graders, may be too simple to detect discipline based differences.

Conclusions

The preliminary work done prior to this study suggested that a Likert-type scale to measure 5th-grade students' understanding of the nature of scientific knowledge is feasible and that the language used in the item statements is likely to be understood by 5th-graders. The study suggested that there is agreement among scientists and science educators that seven of the eight proposed broad propositional statements are accurate and important statements about the nature of scientific knowledge. One proposition—the amorality of scientific knowledge—narrowly missed the importance criteria. Based on the slimness of the margin, and the acceptance of the importance of the proposition by the responding scientists, the amorality proposition can be retained in the model at this time.

The content validity of forty-five item statements has been supported by the survey component of the study. Based on the follow up elaboration of responses, two items—all scientific knowledge can be tested, and some scientific knowledge can never be tested—can be retained despite their failure to meet the prescribes content validity criteria. A rewritten version of a third item—scientific explanations are discovered in nature, not created by scientists—will be subjected to further testing and considered for inclusion in the pilot test instrument.

The pilot test instrument will be subjected to further testing. This evaluation will include its use in a field test with 5th-grade students and review by elementary science education and measurement experts.

In fulfilling its secondary purpose, the study suggested that compared to science educators, scientists are more likely to believe that it is accurate to say that scientific knowledge reflects the contributions of many diverse individuals and more likely to believe in the importance of the assertion that scientific knowledge is amoral; they are less likely than science educators to consider important the statement that scientific knowledge is the product of human creativity. These differences, though statistically significant, were modest, and the overarching result is that the study revealed little meaningful difference between the groups. When the participants were broken down by discipline, there is some evidence that university based scientists may hold views of scientific knowledge that are closer to their professorial colleagues in science education than to fellow scientists working in industry or agencies. Again, however, the differences, even where significant, are modest.

The failure of the study to convincingly identify between-group differences may well reflect the simplicity of the model of scientific knowledge used. The model is intended for use with 5th-grade students. The broad consensus on the proposition and item statements is evidence of the validity of the model and suggests its appropriateness for use with the intended audience. A more sophisticated model than the one used in this study might reveal more meaningful between-group differences than those discussed in this report

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WHAT TEACHERS ARE TELLING US ABOUT REFORM: IMPLICATIONS FOR TEACHER EDUCATION. TEACHER LEARNING OF INNOVATIVE PRACTICES AT A MIDDLE SCHOOL SCIENCE REFORM SITE

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Introduction

Throughout the country, there are many efforts to bring varied forms of change to science education. Successful implementation, though hoped for, is not always guaranteed. Indeed there are many obstacles to change. As one informant in this study[1] described it, "Change is hard."

"A systemic outlook is essential" to successful reform (Anderson et al., 1994) and teacher education is probably a key ingredient to innovative change (Anderson & Mitchener, 1994, p. 36). Teacher knowledge, experiences, and beliefs greatly impact what takes place within the classroom (Anderson, et al., 1994; Connelly & Clandinin, 1988), and research indicates that teachers who "hold beliefs and priorities that are incompatible with envisioned changes" may challenge the success of program reforms (Anderson et al., 1994, p. 81).

What needs to be considered in order to support teachers' learning of new and innovative teaching practices? As educational leaders bring science reform programs to our nation's schools, "greater thought needs to be given to a theory of learning in teaching" (Carter, 1990, p. 307) so that teacher educators have a better understanding of not only what teachers know but also "how that knowledge is obtained or how it changes over time" (p. 307) and what are the "processes or mechanisms by which change is brought about" (Floden and Feiman in Burden, 1990, p. 318). Importantly, research needs to focus on inservice education within the context of schools where the aim is not only to bring about individual teacher transformation, but also deep and long-lasting change in science classrooms (Anderson & Mitchener, 1994, p. 37).

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[1] The research reported in this paper was completed as part of the Curriculum Reform Project, a study of curriculum change in mathematics, science, and critical thinking which was funded by a grant from the U. S. Department of Education's Office of Educational Research and Improvement (OERI Grant #R91182001). The opinions expressed herein are those of the author and the participants in this study.

There are many ways in which teacher learning can be facilitated and impeded in the process of implementing science reform curriculum, and in this paper I will address these factors from both a psychological perspective and from a sociocultural view (Anderson & Mitchener, 1994). Borko and Putnam (1996) point out that "Despite...expectations or demands for change, teachers are not typically treated as learners" (p. 702), and researchers suggest that teacher learning might be best addressed using a constructivist learning theory approach (Borko & Putnam, 1996; Carter, 1990). In addition, the context of the working place, its structure and social dynamics, may serve to support or work against teacher learning of new practices (Borko & Putnam, 1996; Sparks & Loucks-Horsley, 1990).

This paper describes the pathways and impediments to teacher acquisition of new beliefs and instructional strategies as an innovative science curriculum was implemented at Fort Sheridan Middle School[2]. These factors include 1) how staff development was designed with constructivist underpinnings to facilitate teacher learning and how teachers perceived its effectiveness, 2) how the field test process limited the incorporation of teachers' prior knowledge and how that impacted teacher acquisition of new knowledge and skills, 3) how regular and frequent staff development and the creation of a sixth-grade science team provided critical opportunities for interactions with colleagues and outside support personnel and how that contributed to teacher learning, and 4) how such interactive forums diminished after the field test, how old decision-making structures remained in place, and how that impacted further development of teacher knowledge and expertise and of a common vision of the science program among teachers.

Data for this study was acquired through on-site visits at the school site over a period of nine months. Data was collected primarily through 1) classroom observations, 2) observations of faculty meetings, 3) interviews with the program developers, administrators, teachers, students, and university site-coordinators and support personnel, 4) science curriculum materials, and 5) state and district documents that address the reform effort.

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[2] Pseudonyms have been used throughout for the names of individuals, schools, and locations.

The Study Site: Fort Sheridan Middle School

Fort Sheridan Middle School (FSMS) is situated on a large military base in an agricultural region adjacent to a city with a population just above 20,000. At the time of this study, FSMS's student population of about 700 students was 48.3% white, 37.8% African-American, 8.5% Hispanic, 4.4% Asian or Pacific Islander, and 1.0% American Indian or Alaskan Native. About 47% percent of the students were male and 53% of them were female. Most of the student's parents were military personnel (91.9%) and 87.8% of the students lived on the military base. Many of these students' parents were enlisted personnel.

As FSMS made the change to becoming a middle school, some of the junior high faculty moved to the high school and new faculty arrived from the elementary buildings; some junior high faculty remained at Fort Sheridan The middle school science faculty consisted of seven teachers.

During the three years that the science reform curriculum was field-tested, all three of the sixth grade science teachers were elementary-based; Lisa was a sixth grade elementary science educator and Karen and Nancy were elementary generalists. After the field test, Lisa and Karen remained at FSMS. Rhonda joined the sixth grade science team during the fourth year of the reform. Her experience was as a secondary art and home economics teacher, and her science background was embedded in the science coursework required as part of her home economics major.

The seventh and eighth grade science faculty came with experience in secondary education. Two teachers previously taught science at Fort Sheridan Jr. High School, one taught life science and the other taught physical science. Another teacher was transferred from a science position at the district's other junior high school, and the seventh teacher came from the district's alternative high school.

With the implementation of the new middle school structure, the district administration sought a new science curriculum that would provide a vehicle for implementing the teaching approaches and strategies professed in the middle school philosophy.

> We were junior highs...and we had the traditional, very segregated kind of approach of junior high science. Everything was separate--earth science, physical science--each year you got a different piece.
>
> There were several things wrong. One of the things...was that it was not endearing kids to science...when they got to high school, they were taking what was required and they were bailing out....
>
> The other thing that was wrong...was that there was a real... willingness and acceptance of tracking...[and] there's just no place for it....[W]e have an obligation to all the students...The absolute commitment that these kids will be successful. That's what effective schools is all about...if you're willing to be honest to the middle school format, you must give up...tracking...and that's what we aimed for...
>
> [T]hat's what made...the change [to] the middle school--the problems with...only serving some and the failure of these courses to have any meaning as the kid grew. [The schools] were just fertile soil for a change...

The middle school science reform curriculum that was enlisted to bring about this change is part of a national curriculum development project that was funded by the National Science Foundation (NSF) in the late 1980's. This program seeks to 1) develop middle school students' understanding of basic concepts and skills related to science and technology, 2) increase the participation and success of under-represented populations (i.e., girls and minorities) in science classes, 3) improve students' understanding of how science and technology relate to their everyday lives, and 4) promote the development of higher-order thinking skills.

The curriculum is interdisciplinary and is centered around key conceptual themes and major organizing concepts. The program uses an instructional model based on constructivist learning theory where

> ...learning requires active involvement of the student in constructing meaning....[T]he learner must negotiate meaning with his/her learning

> community, make connections with past personal understandings--modifying these prior conceptions if they are not accurate--and build understandings ...that are part of that person's personal conceptual framework...within a learning community or context. (Anderson et al., 1994, p. 2)

In this program, students ask questions, develop operational definitions, gather evidence, construct their own meanings and explanations for phenomena, design approaches and projects that will solve problems and answer questions, and then test their explanations through hands-on investigations. Students use cooperative learning strategies to discuss ideas and to work together to solve problems.

The Tensions and Dilemmas Encountered Based on Differing Values, Beliefs and Experiences

Teachers came to the reform with varying degrees of knowledge about and experience with the instructional approaches of the curriculum and not all teachers held a belief system that coincided with the reform. Some of the teachers came into the field test with a better understanding of these key concepts, strategies, and skills than did others. According to one member of the university science site support staff, those that

> bought into it from the beginning already had a lot of the skills needed to make the program work...It matched up with what they were trying to do...and they saw this program as a help to accomplish what they were trying to do anyway.

For these educators, the opportunity to pilot the science reform curriculum was something they had long awaited.

> For years I have dug for things..."Those of you who teach right from the book, is that good for kids?" You have to look at what's best for kids. I guess that's where I came to leap into [this program]. I had searched and hunted and begged and borrowed and stolen everything I could, to get some

> hands-on science. And [now] you don't have to go try to find all of it. And I was like, "Oh, hallelujah!"
>
> ...[W]e were just in the process of changing over to be a middle school, and it sounded like it fit exactly into the philosophy that we'd been going through and trying to come up with as we wanted to be a middle school.
>
> I felt like we were presented with an option that to me sounded wonderful. The idea of teaching science through a hands-on program and more from a...process rather than a product sort of viewpoint...that really made a lot of sense because the kids...learn by doing.

Some of these teachers had already successfully used cooperative learning strategies in their classrooms. Some of them were working to make changes in their approaches to teaching by working with university personnel to develop and adapt effective strategies for outdoor, hands-on science activities for their classrooms.

For other teachers, the science reform curriculum was very different from what they normally did in their classrooms.

> [T]hey didn't have the same philosophy...and they weren't so skilled.... There were a couple of teachers...who weren't convinced that the...new way was...better than the old way...and had some problems adjusting... this was a total departure from what they wanted to do in their classrooms and so they did not have that same kind of philosophy...of what ought to be going on in the classroom. Teachers that were more teacher-directed had [a] harder time. Those that were more student-oriented let the students discover and were more successful.

Such teachers felt that they had been teaching successfully for many years and saw little need to make changes in their teaching philosophy. For some, then, there was "an inertia and resistance to be overcome."

As teachers came to this reform with a variety of teaching backgrounds and experiences, there were also questions and concerns about how supposedly "non-science" people could teach the curriculum and how the program best utilized the expertise of those who had a science background. There were questions about student assessment--what was it like with this program? There were concerns that the administration would not adopt the published program at the end of the field test and that the field test would be more work for teachers. Some teachers felt that there was already a great deal of change taking place with the move to the middle school and that the field test would add to the stress.

Some science teachers felt that they were not being fully informed about the program; as one teacher explained it, "There wasn't any information on the program...They had no books for us to look at, they had nothing..." Others felt that they were not being given any choice; if one person wanted to do the program, they all had to do it. "We were told we had to do it," one teacher explained. Another teacher stated, "...[I]t was voluntary; then it wasn't."

Two faculty members were definitely not in favor of the new program. "They wanted science as it was." "They felt that that wasn't what they wanted to do as teaching science." One of the dissenting faculty members quit because of the decision to field test the new curriculum. He basically said, "I'll not teach it" and he left the district.

The principal, new to the school, was supportive of the program as "it was a good opportunity...to do something new." He said, "You know, we'd like a consensus" from the faculty.

It appeared, though, that the remaining teachers' willingness to commit to trying the program and to work together was what allowed the field test to happen. One teacher related that, "I think we had the belief that 'this can work'" and that the faculty held elements of "enthusiasm" and "hope." Another teacher stated that

> ...I think that most everybody...that's here now is...real open to giving it a try....I think that what really helped keep it going is that everybody...was really willing to give it a shot....[T]he people that we had here... really made it work.

Most of the teachers that had come to the middle school did so because they wanted to and "most of them were change people." Other teachers, though not in favor of it, reluctantly said, "I will give it a try." As the implementation process began, "The enthusiasm and success of the other teachers" and the support and "encouragement that they gave" were helpful in motivating those who were hesitant.

So it was important to look not only at where teachers were in the process of reform, but also where these teachers began. For some teachers the reform process was an opportunity to use a program as a vehicle to implement new approaches and strategies that reflected where they were and where they wanted to go. For others, it became an opportunity to reflect on long-held ideas and beliefs about learning. A university staff member pointed out that "Some people invite change....Some of the more reluctant initially gained a lot from the experience. Change doesn't happen overnight. It takes longer for some people."

Teacher Learning

Teachers, administrators, program developers, and university support staff all believed that it was valuable for teachers to have a background in the philosophy and goals that frame the program.

> I think that one thing that's super valuable is...not to just throw this in (and) say, "Here, this is what you're going to teach."....[Y]ou do need a lot of the training and a lot of the background and the philosophy of it to make it successful 'cause you've got to be in that mind set, "OK this is what we're trying to go towards."

As constructivist learning theory provides the basis for the instructional approaches used in this reform, it also provides an underlying framework for discussion of teacher learning during the reform process. The reform curriculum provided students with opportunities to construct their own understanding. Students 1) reflected on personal knowledge and prior experiences, 2) participated in interactive, hands-on activities, 3) asked questions, solved problems, and used new knowledge, and 4) communicated and worked with others in cooperative teams. The science education standards for this state paralleled the learning goals and instructional approaches of the reform and, interestingly, the state set these curricular standards for "teachers as well as students." The curricular standards state that

> the following characteristics must be present in a transformed science program.
>
> Teachers as well as students must:
>
> --be challenged to become skillful thinkers and problem-solvers
> --work together in groups and teams
> --be creative
> --value curiosity
> --persevere in long term investigation
> --communicate effectively
> --apply what they learn to authentic needs within their own communities
> --be flexible and adaptable to changes and discoveries
> --make connections between the fundamental concepts of our natural world as well as between science, technology, and society.

What was valued as important for student learning was equally important for teacher learning.

In addition, the program developers decided to use the instructional model of the curriculum as the model for professional development. The teachers needed to experience "dissonance" with their old approaches; they had to become uncomfortable with what they had been doing to see the value of what they were implementing. During staff-development and early in-service sessions, facilitators were clear about the fact: "We teach you the same way that you can teach your students about the program." Therefore, it's important to address teacher learning of new philosophies, beliefs, and instructional approaches through a constructivist framework.

Staff Development and Support for Change

In order to present teachers with the philosophy and skills of the new science curriculum, program developers provided them with staff development in order to "give field-test teachers first-hand experience with the philosophy, goals, teaching strategies, activities, equipment, and materials of the curriculum...[and] opportunities to learn more about cooperative learning, the instructional model, and interdisciplinary curriculum development." Throughout the field test, inservice sessions provided a time for teachers to share ideas on how the science program was working in their classrooms and to talk about learning theory, alternative assessment, cooperative learning, content learning, and management strategies. Teachers were asked to think about their teaching philosophy and to draw upon their prior knowledge about learning. For example, constructivism was presented as a theory of learning--"How do you know what you know?" Teachers would discuss how these learning concepts and instructional strategies were applied in the reform curriculum.

Teachers reacted differently to this approach. For one particular teacher, it seemed evident that the in-service provided an opportunity to reflect on long-held beliefs about student learning. A university staff member stated,

> We brought up some of those issues. I will say that they weren't very well received...some of these teachers [were] sitting there going, "Who cares about this?" although a couple of them got into it. And one thing that I thought was interesting, is [a] teacher...that started out very antagonistic towards the program...interacted the most on those kinds of discussions....I think a lot of the reasons why he started changing his mind was that he started questioning some of the assumptions about what science is....So for most of them...it was like this is just ivory tower stuff you hear in a university...but I

> think there were a couple who it was important for--this one individual in particular.

Concepts key to the science program and cooperative learning strategies were presented using a constructivist approach so that teachers were being taught these concepts in a way that they were expected to teach their students. After the initial staff development sessions, though, the instructional model and cooperative learning strategies were not used consistently during in-service institutes with teachers.

One of the teachers described the difficulty he had with learning the new approaches and understandings associated with this program and how the staff-development and inservice sessions were rarely helpful in making a shift from old teaching approaches to new.

> They're supposed to be supportive, because they had these...meetings....It wasn't to me very productive because they gave us the new version of [the field test materials], and then we just spent [time in]...groups...just talking about a section....That's not how I learn. I have to do something...

For example, Andrew cited cooperative learning as a particular problem area. Teachers, program developers, and university support staff all emphasized that effective cooperative learning strategies are critical to successful implementation of this science program, and one teacher spoke about how the most difficult change that she encountered with the reform was teaching students how to work in cooperative teams. Though cooperative learning was covered often during in-service sessions, for Andrew, it was not immediately effective in helping him adopt new beliefs and instructional approaches. After three years of field-testing the curriculum and attending in-services, this teacher spoke about how valuable a cooperative learning in-service would be as he had had no experience with it and his lack of knowledge of cooperative learning "affects everything I do because I don't feel like I'm effective with this..." He found that he had some students that just could not "work with others" and he tended to separate them and have them sit in desks away from the tabled teams.

It is important to point out that Andrew's beliefs about student learning appeared to conflict with the beliefs necessary to successfully implement cooperative learning approaches in the classroom. Whereas cooperative learning fosters a belief in effective learning situations with heterogeneous groups of children, Andrew struggled with a perception of teaching and student learning that required ability grouping. Four years into the reform, Andrew came to realize that tracking was embedded within his belief system about student learning, that such a belief system conflicted with the philosophy of the reform curriculum, and as a result, the new curriculum was not working successfully for him or his students. As he struggled, he also clearly realized the need for assistance for further change.

> I've been trying for two years to take the class on cooperative [learning]....I borrowed a book to read, but that doesn't do you any good if you don't have people there....I need to be involved....I need to have it functional for me.

He pointed to the fact that another teacher, Eric, had already had a cooperative learning class "and it proved very helpful" for him. Eric indicated that, indeed, a cooperative learning class had been helpful.

> [T]he biggest thing that has helped me out is taking a class on cooperative learning....The very first year we field taught I took that class at the same time. So I really felt that that got me into the correct mind set of...what does it really mean to be...a cooperative class?

However, as the reform curriculum was piloted in 1990, Eric was open to the science reform; he felt that it supported the middle school philosophy. His choice then was to immediately take a cooperative learning class to aid him in facilitating the changes within his science classroom. In contrast, Andrew was unsure about the benefits of the program and was hesitant to implement the curriculum in his classroom. After four years of field-testing and implementation, though, Andrew came to a critical place. He saw the differences between his belief system and instructional strategies and those of the reform and he perceived that further training in this key aspect of the program would be of great value to his teaching.

Andrew enrolled in a cooperative learning class. Though participation in the class failed to provide him with answers to all of his questions, he began to reflect on the key social skills that would strengthen his students' cooperative skills. His new approach contrasted with his previous plans to ability-group children.

Andrew also talked about the need to have learned such instructional approaches as he worked with his students. Using the instructional approaches with other adults was not, in itself, effective. He saw that better teacher learning would have ensued had he been able to practice those approaches with children and had conversations regarding that practice with experts and peers.

In sum, it appears that staff development and in-service served FSMS teachers in different ways. One member of the university support staff emphasizes that it is important not to "expect everyone to be in the same place" in the change process, "but moving along..." Therefore, it is critical when implementing reform to consider the amount of time teachers may need to reach dissonance with their long-held beliefs and approaches. It is important to ensure that support and staff development (through in-service, coursework, peer coaching, and university support) are available to them at that juncture. It cannot be said that three years of staff development necessarily provided enough support to bring all teachers at FSMS to a place where they could successfully implement an innovative curriculum. The staff development process, though, may have possibly placed them in a better position for change later in the implementation process. It appears that more and varied types of support are needed for continued teacher learning.

For those already committed to change, in-service training aided them in further developing important concepts and skills necessary to successfully implement the reform curriculum in their classrooms. In order for continued change, additional support seems important for these teachers as well. (This point will be discussed further below.)

Teacher Learning and The Practice of Field-Testing

During a field test, teachers are not supposed to modify or adjust the curriculum activities to fit their style of teaching or to provide a more successful lesson based on their prior knowledge and teaching experience. Field-testing requires the teacher to teach the curriculum as it is written. Therefore, one needs to consider the impact of the "rules of the field test" on the construction of new teacher knowledge. Reflecting on prior knowledge and experience is a key component of constructivist learning (von Glasersfeld, 1992), yet teachers were required to set aside their prior knowledge of science teaching as they field-tested the reform curriculum.

Most of the teachers at FSMS felt very constrained because of the this during the field test. A university staff member explained,

> ...[M]ost of these teachers were...what I would call pretty good teachers... teachers who didn't--even when they had a traditional program--didn't just teach the textbook. OK, they were doing their own thing, supplementing it, cutting out and adding things all on their own...these are experienced teachers. They taught for how long and they have some knowledge and some background about what they think is important and activities that work for them. So now they're forcing this, field-testing this curriculum. And one of the things we tried to emphasize was that "We want this field test to be a field test of what's written, not necessarily a field test of how good a teacher you are in terms of being able to take what's written and adapt it"...So in a lot of ways they felt very constrained by this. They wanted to take these ideas and run with them and go wherever they wanted with them.

A 6th grade teacher described field-testing as "exhausting."

> [I]t was really frustrating to know that, I think we could do it better if we changed this. But in those first two years not feeling like I [had] the leeway to do any of that because I needed to teach it exactly as it was written so that I could give them real feedback on what they were trying to accomplish....I was free to make suggestions at any time, but I didn't feel like I could do it first and then suggest.

This possible constraint to learning was possibly mediated by the fact that program developers recognized "the need to treat teachers as professionals" and as "co-developers." One teacher saw her role as "trouble shooting. In some cases [as] nit picking."

Teachers (and students) were asked to give comments and opinions regarding the curriculum, and some of their ideas were reflected in the second field test edition. Some teachers would retry activities and "give it a new twist," and they were paid for any ideas that were used in future materials.

However, the field test "rules" for the teacher were explicit--they were to teach the curriculum as written and not draw on their personal knowledge and experience to modify the materials as they taught. As a result, dissonance between old and new ideas, and ultimately the construction of new knowledge, may have been delayed for some teachers. It may have encouraged the construction of dual knowledge and practice systems--"teaching as I know it" and "teaching as the program outlines it"--and may have ultimately facilitated some teachers' continued reliance on past strategies and beliefs. Some of these approaches were in evidence in various degrees in some classrooms in the form of quizzes, extended use of old textbooks, teacher lecturing, and independent seatwork.

In addition, some of the teachers talked about how the field-test activities were poorly written and just did not work in their classrooms.

> It was a mess! Oh my god, that first year, it was, the book was horrendous. Things didn't work. When you'd get into it...it was just a mess....I was so busy trying to figure out what was going on in the book....I was really upset with this book. It was terrible.

> [S]ome of it was very bad. Some of it didn't work. Some of it took forever....[T]he kids couldn't understand it, and it was placed at the wrong level.

Some teachers also complained about the poor quality of equipment. "They sent...cheap things that didn't work. We [had] pieces of equipment that [were] supposed to do things that would not."

Field test instructional materials and equipment may not be the best materials to use with teachers who have little knowledge and understanding of the framework on which the curriculum is based and who feel successful with long-held teaching practices. It is unlikely that teachers will come to a place of dissonance and/or dissatisfaction with teaching practices that they view as successful and abandon these approaches for those that are not. Furthermore, it may be difficult for individuals to reconstruct and develop new beliefs and approaches with materials that are not working at their optimum.

Teacher Learning: Communication with Others

In the Context of Staff Development and In-service

What seemed most valuable to teachers during the in-service sessions, were the opportunities they had to talk with other teachers about the problems that they were experiencing in their classrooms and to hear about the solutions that other teachers were employing. As students in this science program problem-solved and created and answered questions in cooperative group settings, likewise teachers constructed their own knowledge through conversations with their peers. Eric pointed out that

> It was probably more helpful honestly to get together with other schools... and just talking at lunch and saying, "Well how did this go for you?" "What did you do on this?" "Oh yeah that would work for me." and...exchanging ideas in that way I think was more valuable than some of the stuff they had us do....[W]e tried a few of the projects and...it helped seeing them the first time, but I think the biggest thing was just talking, being able to talk to other people and saying, "I had this problem with it." "Yeah, I had that too. What did you do to solve it?"

During the in-services, teachers would examine new units and work through some of the activities in the new materials to become familiar with them and to address any possible difficulties. As there were the difficulties with the field test materials, some teachers valued the opportunities to "talk about it" and "have their say" that "it [was] not all perfect" and say "what [was] wrong." They needed to talk about what was going well and what was not. In these settings, teachers needed to be problem-solvers. At the in-service, they did such things as write their problems out on 3 x 5 cards that were then shared with other teachers who would give them a "fresh perspective" about how they could solve their problems.

In the Context of Working Together within FSMS

Some of this valued communication continued to take place outside staff development sessions. Beginning with the first field test year, the sixth grade science teachers at FSMS formed a disciplinary team to plan and to coordinate their classroom activities. It worked "beautifully." They would "plan what they were going to do and help each other. Even within the early field test edition, they didn't have much [of a] problem..." As a university staff member described it,

> The three would structure time. The fact that there was somebody they could go and talk to....Teachers that were more isolated...would call [university support personnel or the program developers but it was] not the same as having a colleague. [It is] very important to have somebody else you can communicate with. The people who got together and shared common concerns were less apprehensive.

The sixth grade team attributed their working together as "invaluable" to their success in implementing the program. Lisa emphasized, "We wouldn't have had nearly the success if we hadn't done that. I really think that we had an easier time with it than anybody else because we planned together." The 6th grade science team has stressed to other teachers that team planning would really make the change to the new program much easier. Karen pointed out that team planning was very helpful to her science team.

> I think that we get an awful lot from each other. I think that (other teachers) might find more support than they expect from each other. "Gee, this didn't work. What can we do?" You know, "This is a good idea, but it's not working." If they would do that, I think it would help.

Their meetings, held once a week during a common planning time in the afternoon, included a sharing of problems, solutions, and successes. The issues discussed included: 1) the materials that are necessary for activities, how they are organized for best use by the students, and the possible problems that can arise with them, 2) how to structure the class for different activities (i.e. teams, size of teams, whole class activities), 3) the modifications to the student text needed to aid students, to simplify the task, or to make the approach to the task more sensible and/or organized, 4) the students' approaches to learning and the successes and obstacles that students experience, 5) the various instructional strategies individual teachers are using (i.e., modeling), 6) the time frames needed for various activities, 7) the methods of student assessment, 8) the sharing of teacher preparation tasks (i.e., locating, acquiring, and copying materials), 9) the science content, and 10) the role of the teacher and the role of the student.

As a new member of the sixth grade science team, Rhonda felt as if the support that she received from her science team was very helpful in making the change to her new teaching assignment. "[It is] easy when you have support." During team meetings, Rhonda asked questions like: "How long will it take me to do this?" "Should I plan one class for this reading?" "What did I forget?" "Do you have a problem with your kids over-watering their plants?" Her teacher's guide was filled with yellow sticky notes to remind her of things that were not in the book. They were things which Karen and Lisa had shared with her and which were based on their three-year experience with the program.

Among the FSMS science staff, the sixth grade was the only grade level that team-planned its science. The eighth grade science teachers, though, helped each other, problem-solved, and shared equipment. The 7th grade teachers appeared, though, to have little communication with each other.

Across grade levels, Eric and Lisa, eighth and sixth grade teachers, shared informally what was happening in each other's classrooms and seemed to be comfortable with their knowledge of each other's programs. In general, though, there appeared to be little communication, collaboration, or shared vision between the science teachers of the different grade levels. When describing the cross grade-level communication, some teachers described the situation as "fragmented."

Reforming School Structures for Continued Change and Growth

These science teachers perceived themselves as being "fragmented" as opposed to having a shared vision. It appeared that what had handicapped teachers to further develop the science program and extend science reform was the school and district structure. What had not occurred within the district to facilitate the communication, interaction, and collaboration between teachers was the redistribution of decision-making power from the administration to the science educators at FSMS. During and following the field test, decisions regarding the science program remained the responsibility of the district director of secondary education. Within the school, day-to-day decisions regarding equipment and supplies continued to be made by the department chair, a long-time resistor to the reform.

Importantly, district and school structures and policies conflict with the philosophy of this reform. In the reform, the role of the teacher in the classroom changes from the major source of information and the transmitter of that information to a facilitator or coach who engages and encourages students to explore and form their own explanations. The same kind of role change needed to occur with regards to the administration and the teaching staff at FSMS. Administrators needed to be facilitators and coaches, where they engaged and encouraged science faculty to problem-solve, inquire, and communicate with each other in cooperative and collaborative teams and with other teachers and experts outside their school so that they could further develop effective classroom strategies and approaches, set program goals, and develop new assessments.

Without forums for communication and new decision-making structures, these middle school science teachers were without means to develop a unified direction for further change and growth. Such structures, such as grade-level science teams (like the sixth grade team) and science faculty councils, would provide teachers with opportunities to continue the valuable dialogue and learning that took place during in-service institutes during the field test. Without such forums and structures, further teacher learning and program developments are impeded and full implementation of the reform becomes uncertain.

Summary

Key to constructivist learning for students is the need to communicate as they work through the process of scientific problem solving and inquiry. Students can verbalize their beliefs regarding problems and solutions, which provides them with opportunities to understand their ideas and those of others more clearly and to see inconsistencies in their thinking (von Glasersfeld, 1992). Working with others also allows for scaffolding of thinking between group members in order to complete complicated tasks, answer questions, and solve problems (Resnick, 1992). In addition, Resnick (1992) points out that social interaction is important to the development of thinking skills in that it provides opportunities for individuals to model and observe thinking strategies--how one analyzes and approaches a problem and puts together arguments.

Important to consider here is that as these approaches are necessary for student learning, they are also critical to teacher learning. The state Department of Education includes "teachers as well as students" in their curricular standards for a "transformed science program." Teachers and students must work in open systems. They need to "work together in groups and teams," "communicate effectively," persevere in long term investigation," and "apply what they learn to authentic needs within their communities." These practices apply not only to the learning of science and technology, but also to the learning of new teaching and learning philosophies and instructional approaches. It appears, though, that with the conclusion of the field test, a "closed system" emerged where communication between science teachers at FSMS and between these teachers and outside support personnel is neither supported nor encouraged.

As the valued opportunities for teacher learning through communication and collaboration with others diminished after the field test, teachers were isolated from many situations and individuals important to their personal learning and their professional growth. Beliefs about the processes for teacher learning need to be consistent with beliefs about the ways in which students learn. Therefore communication, cooperative interactions, and collaboration between teachers are critical to the future development of their learning and teaching.

Support for Staff Development

It is valuable to examine the environment systemically, as "a combination of endeavors that relate to each other and in combination have a significant impact in the context in which change is being sought" (Anderson & Mitchener, 1994, p. 36). It is important to be attentive to the context of staff development (Sparks & Loucks-Horsley, 1990) as factors there may work against teacher learning of innovative ways to teach (Borko & Putnam, 1996).

> It requires attention to organizational and political considerations. Actions taken at the national, state, district, school, and classroom levels...can interact to support change in a common direction, or they can counteract each other in such a manner that change is defeated. And even though all actions taken are complementary, there is the possibility that the omission of some particular action or actions could stall what would otherwise be a successful reform effort. A vision of what should be must be combined with a systemic process of working toward that vision (Anderson et al., 1994, p. 4).

In addition to the structural factors discussed in the previous section, the following discussion serves to address the contextual factors critical to teacher learning at this site.

Administrative Support

The administration's support for the reform was evident in 1) the strong push to implement the reform curriculum, 2) the support of hands-on, activity-based classrooms, 3) the release time provided teachers for in-service and staff development and the support of an electronic bulletin board during the field test years, 4) the purchase of the published curriculum materials, and 5) the acknowledgment for the need for congruency between state assessment and the district's philosophy in science education.

The district administration's vision for the future was one of breadth, as it included the implementation of science reform curricula initially at the middle school level, but then later at the elementary and the high school levels, thus securing consistency in philosophy throughout the district. Importantly, the initial support of the administration was a critical factor in the implementation of the science reform curriculum at FSMS. Despite the high interest for the reform on the part of some of the science teachers, there was so much resistance from others, that without the strong administrative push, it seems highly unlikely that the program would have been implemented. However, as a result of this top down approach, some teachers felt that they were not given any choice whether to participate in the field test or not ("we had to do it.") which resulted in some negative feelings towards the reform and some teachers remaining resistant to the change. The top-down strategy thus served as a door opening agent for implementation, but also served as an obstacle to the change process.

Sparks and Loucks-Horsley (1990) report research that indicates that where top-down policies establish the direction and expectations within a school district, a supportive environment for teacher change requires involvement by teachers in formulating goals. Yet, as the field test ended, the district administration did not give teachers support, encouragement, or the power to make decisions and to take on responsibility for setting program goals in depth, developing further instructional strategies, and developing new classroom and district assessments. Administrative support weakened in that teacher opportunities for learning through staff development and through communication and collaboration greatly decreased.

Support from Program Developers and University Support Staff

Communication between the teachers and the program developers occurred not only through staff development and in-service meetings, but also through an electronic bulletin board. Though the bulletin board continued at the program developers' headquarters, one teacher complained that the school removed their modem after the field test. Teachers with "this doesn't work" situations then needed to contact the program developers indirectly through an 800 number with the publisher or by writing the program developers directly.

The university (SU) provided important support in the context of in-service education. University support staff would also pay regular visits to FSMS and visit with teachers in their classrooms during the field test. They would meet with teachers and ask "how's it going" and give help. When the field test was complete, this supportive framework was lost due to the end of funding.

State Support

Under the leadership of a new State Commissioner of Education and the progressive vision of a state legislature, the State Department of Education began to develop science outcomes for the schools throughout the state just as the faculty of FSMS began to field-test the science reform curriculum. As one reviews the state's mission statement for science education and its statement of philosophy, one would think that the state's writers had at some point collaborated closely with the writers of the reform curriculum. The mission statement reads: "The mission of science education in [the state] is to develop all students into life long learners who are reasoned decision makers..."

The science education standards for the state paralleled the learning goals and instructional approaches of the reform. Further, the state described the characteristics of quality science instruction as including:

> —teaching consistent with the nature of scientific inquiry
>
> —beginning concept development with questions, events, or phenomena that are interesting and familiar to students
>
> —engaging learners actively
>
> —using team approach and cooperative learning techniques
>
> —de-emphasizing lower level memorization skills and emphasizing the higher level thinking skills
>
> —insisting on quality communication
>
> —concentrating on the collection and use of evidence
>
> —valuing respect, risk-taking, equity (gender and ethnicity), and inquiry in the classroom...

Though the state's development of reform standards was congruent with the science reform curriculum implemented at FSMS, it was not the impetus for the reform. The state did not dictate change for the Lincoln County schools. They happened simultaneously in conjunction with national movements for change. State administrators hope that new state assessments that are focused on process science will "drive" problem-solving instruction. They talk about how "people assess what they value" and by assessing students for the development of process skills, state educators will begin to teach process science.

Conclusion

What needs to be considered in order to support teachers' learning of new and innovative teaching practices? Borko and Putnam (l996) present the following features important to successful learning experiences for teachers that are consistent with the facets of constructivist learning. They include:

> •addressing teachers' preexisting knowledge and beliefs about teaching, learning, learners, and subject matter;
>
> •providing teachers with sustained opportunities to deepen and expand their knowledge of subject matter [and here I would include their knowledge of learning and teaching];
>
> •grounding teachers' learning and reflection in classroom practice; and
>
> •offer ample time and support for reflection, collaboration, and continued learning. (p. 70l)

It is important that teachers have a belief in and a good understanding of the reform's philosophy, the curriculum's instructional model, and the program's teaching strategies in order to teach the program effectively in their classrooms. Some teachers at FSMS came into the field test with a better understanding of the program's key concepts, strategies, and skills than did others. These teachers viewed this program as a much desired vehicle to help them implement new instructional approaches. For these educators, the field test materials and the staff development institutes provided them with teaching strategies and instructional materials that they had long sought on their own. These teachers had already been on this pathway and the reform supported their long-time personal endeavors for change.

However, other teachers did not come with this background knowledge and experience. For some, the science reform curriculum was quite a departure from what they normally did in their classrooms. In addition, they felt that they were successful in their teaching, saw little reason to change their teaching practices, and were uncertain, unconvinced, and resistant to the new curriculum. Yet, for them, the program implementation and its concurrent staff development and in-service served as an opportunity for professional growth--knowledge could be gleaned about the program and long-held beliefs were recognized and possibly challenged.

The National Center for Research on Teacher Education (1991) points out that if educators are going to be effectively assisted in adopting innovative programs, they need 1) a chance to think about why innovative methods are better than more traditional practices, 2) examples of such methods, and 3) an opportunity to "experience...firsthand" the approaches as learners. Considering this, staff development and in-service workshops were valuable to some teachers as they were able to experience first hand the activities and approaches of the program. Yet some teachers felt that it was not enough to only experience these instructional approaches with other teachers; it would have been more valuable to have used and practiced these strategies with students in the classroom and to have had immediate support and feedback from peers and/or experts in that context.

It is important to teach "teachers as learners in a manner consistent with the program's vision of how teachers should treat students as learners" (Borko & Putnam, 1996, p. 701). As teachers were presented with the framework of the reform and the instructional strategies of the curriculum, program developers used the same pedagogical approaches with teachers that the teachers were expected to use with their middle school students. Yet program developers and administrators need to carefully consider providing support for teachers over longer periods of time as some educators did not reach dissonance with long-held beliefs until later into the reform.

In addition, as students worked in cooperative teams to ask questions, generate solutions, test out ideas, resolve problems, and construct new ideas, the same learning process held true for teachers as they met to discuss the workings and failures of the new curriculum they were implementing. Communication between teachers, university support personnel, and program developers appeared to be a key component to teacher learning and to facilitating the implementation of this reform curriculum. What seemed to be of most value to the teachers in this study were the opportunities they had in the contexts of staff development institutes and in-service education to talk with other teachers about the problems they were experiencing and to hear and to talk about the solutions that other teachers were utilizing. It was in these settings that teachers could share and build on each other's ideas and could examine diverse approaches to the problems they were experiencing in their classrooms.

Of special interest and importance is that these learning contexts for teachers paralleled the learning contexts provided for students in the reform curriculum. For both students and teachers in this science program, the social construction of knowledge through cooperative and collaborative interactions appeared to be critical to overall learning. The state Board of Education indicated that for both teachers and students "communicating effectively" and "working together in groups and teams" were key characteristics of a "transformed science program" the goal of which was to develop teachers and students into "lifelong learners."

However, these learning contexts greatly diminished when the field test ended and its structure was no longer in place. The sixth grade science team still remained in constant and supportive dialogue and there was some communication between eighth grade teachers, but in general, teachers found themselves quite isolated from teachers in other grade levels and from individuals with expertise outside their school. This greatly impacted their further learning and development as teachers as well as the further development of the science reform within their school. Most science teachers continued to experience some frustration with aspects of the program--some more than others. Some educators were just beginning to experience dissonance between their long-held teaching beliefs and the underlying framework of this reform. Also, critically, there was no unified vision for the further development of this reform within the school. Teachers held individual goals and objectives that were valuable, but they acknowledged that as a faculty, they were "fragmented." Communication opportunities and new decision-making structures, such as science teams, needed to be created, encouraged, and supported so that teachers could further develop instructional strategies, assessments, and future goals of the reform.

Important to consider when reflecting on teacher learning, is the frustration felt by the teachers as they implemented field test materials as they were written. Within the framework of the field test, teachers were asked to set prior knowledge and experience aside, not modify curriculum activities, and teach the pilot materials as they were written. Following constructivist learning theory, their personal learning may have been hampered by these field test "rules," and dual belief systems may have been developed.

Change can be a difficult and complex process. Importantly, science teachers at FSMS differed greatly in how much they incorporated the program's key features into their classrooms after four years of staff development and working with a new curriculum. What is difficult and complex about incorporating reform in science classrooms is coming to recognize and understand the many factors, including the ways and practices that support teacher learning, that are critical to its success and to have knowledge of the obstacles that can inhibit its progress. With such knowledge and understanding, we can then foster action that will support the change and, importantly, address the limiting factors. In sum, change is, indeed, a long and intricate process and it needs continued nurturance, sustenance, and support in order to persevere.

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